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COMPRESSED AIR

A MONTHLY MAGAZINE DEVOTED TO THE USEFUL APPLICATIONS OF COMPRESSED AIR

Vol. XII OCTOBER, 1907 No. 8

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IS THE PACKING FOR

Air Compressors

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is made of a substance that heat cannot affect, and owing to our thorough method of lubrication carries its own lubricant, which keeps it soft and pliable and makes it last far beyond other packings under the hard conditions of air pressures.

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Pack the globe and other small valves with PALMETTO TWIST.

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Published by THE COMPRESSED AIR MAGAZINE CO., Easton, Pa.

NEW YORK, Bowling Green Building. LONDON, 114 Queen Victoria Street.

Classified Buyers' Guide, Page 6. Index to Advertisers, Page 4.

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AIR COMPRESSORS

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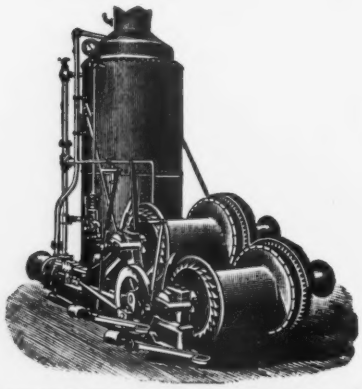

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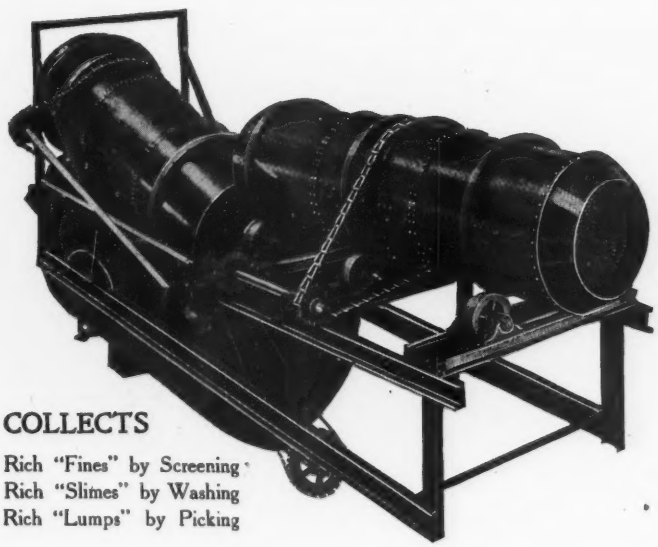

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FOR ECONOMICAL MINING SERVICE

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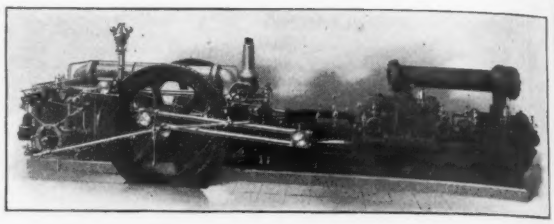

(1) It is equipped with full Corliss valve gear on both high and low pressure steam cylinders, which reduces its consumption of fuel to that of the best class of Corliss Cross Compound Compressors.
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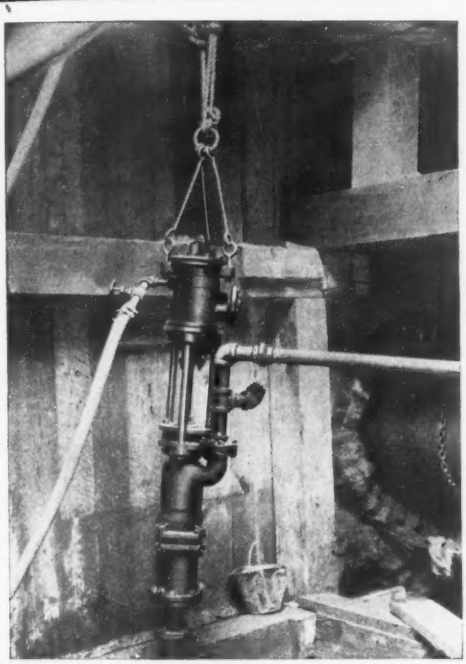

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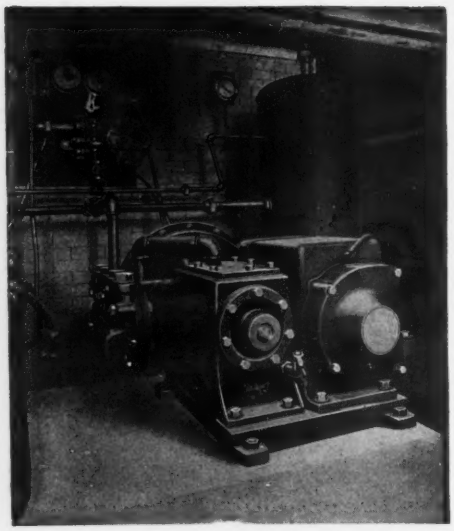

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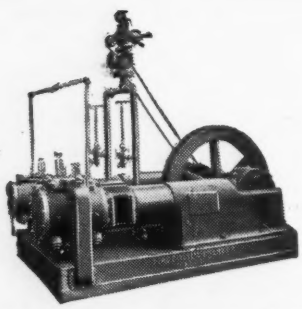

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(Continued on page 12.)

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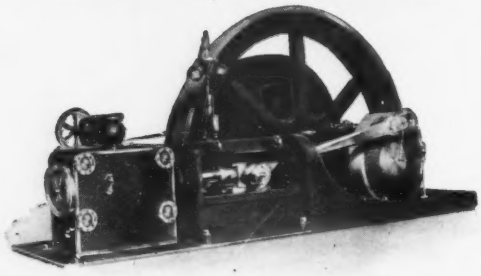

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The classified section of a publication is a good indication of its circulation and quality as an advertising medium

Note these Figures for the Last Eighteen Months, Jan. 1, 1906, to July 1, 1907

	Situation Wanted Advs.	Situation Open Advs.	Miscellaneous Advs.	Total
Engineering News,	**5630**	**2229**	**2395**	**10254**
Nearest Competitor,	1333	943	525	2801

Out of a total of **13055 Want Advertisements** carried by ENGINEERING NEWS and its nearest competitor, nearly **80%** WERE IN Engineering News

This accomplished notwithstanding our prices for **50 per cent.** of these advertisements were **double** those of the nearest publication

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Situations Open, 3c. a Word. Situations Wanted, 1½c. a Word
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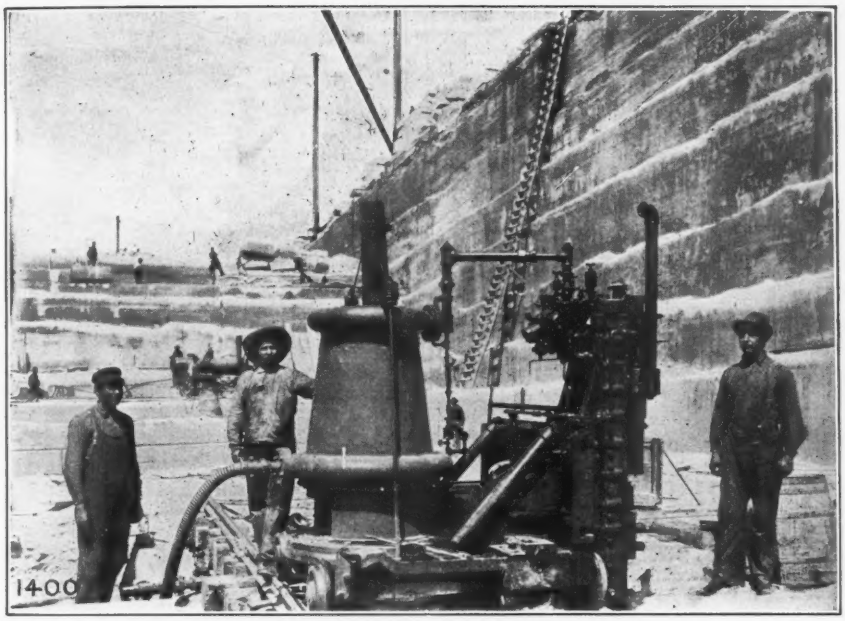
Subscription, $5.00 per year; $2.50 tor Six Months; Trial, Ten Weeks, $1.00

ENGINEERING NEWS, 224 BROADWAY, NEW YORK

"MONITOR" CHANNELERS



One of the "Monitor" Channelers with Air Reheater in use in the Grey Canon Quarry of the Cleveland Stone Company, North Amherst, Ohio.

The Cleveland Stone Company of Cleveland, Ohio, and its allied interests—the largest users of stone channelers in the world—are to-day using 62 Ingersoll-Rand "Monitor" Track Channelers in their various quarries. Their latest orders were placed for Ingersoll-Rand Channelers, after exhaustive tests in their great North Amherst Quarry had shown the "Monitor" to be superior to all other types and makes, on the five following points:

Cutting Capacity.
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Ingersoll-Rand Rock Drills and Air Compressors are used exclusively in all of the Cleveland Stone Company's Quarries.

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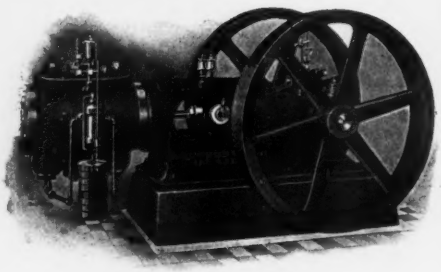
AIR COMPRESSORS



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Of Single, Duplex, and Two Stage types—Belt, Steam or Motor Driven. Designed for high efficiency and economy of operation.

Our Illustrated Catalogue describes the machines in detail. Mailed free on request.

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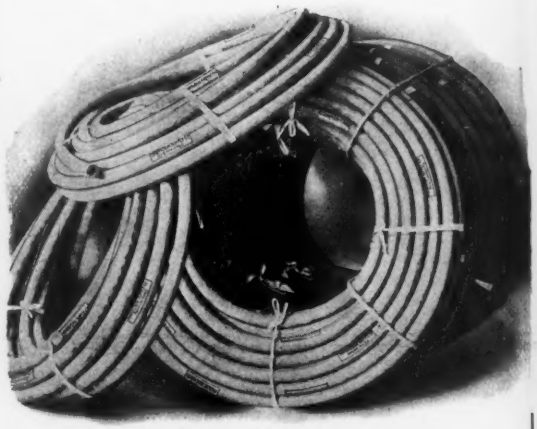

We sell Supplies of all Kinds pertaining to Pneumatic Tool Hose, including Hose Bands, Wire Fasteners, Steel and Iron Nipples, M. & F. Nipples, Stop-Cocks, Pneumatic Polishing Machinery and everything pertaining to Granite and Marble Polishing Supplies and Machinery.

We are the largest House in this country handling such goods exclusively. Write for our beautiful illustrated catalogue today. It is free to all.

Harrison Supply Company

NATHAN C. HARRISON, General Agent

5 and 7 Dorchester Avenue Extension, Boston, Mass.

Tell the Advertiser You Saw His Ad. in COMPRESSED AIR.

COMPRESSED AIR

AND EVERYTHING PNEUMATIC

Vol. XII OCTOBER, 1907 No. 8

A TYPICAL POHLE AIR LIFT

The half-tone shows an interesting and highly successful air lift installation at Garden City, Kansas, the information concerning it being furnished us by The Stearns-Roger Manufacturing Company, Denver, Colo.

THE POHLE AIR LIFT AT A SUGAR FACTORY.

The building shown is a beet-sugar factory. The working season is from the beginning of September to about New Year's, and during that time the water consumption is about 4,000,000 gallons per twenty-four hours.

There is a strong underflow in a stratum of gravel underlying the entire section at Garden City and extending on both sides of the Arkansas River. The sand and gravel is about 45 feet thick from the surface down; then comes the clay. The water flows through this loose gravel parallel with the river. It is of course on top of the clay stratum.

A duplex Type X-1 Imperial compressor, 16 and 25 by 20 inches, was placed in the factory on the main floor, about where the line of wells shows as coming against the factory wall in the half-tone. Then twenty-five wells were sunk, practically in a straight line from the factory toward the river. The wells are 40 feet apart and each well is 60 feet deep; running 40 feet to the clay, and then the bal-

ance in the clay, so as to get sufficient submergence for the Pohle air lift system.

In sinking the wells 16 inch wrought iron pipe was used, weighting the top of the pipe and taking the gravel from the interior by means of the ordinary sand pump, the pipe gradually sinking until the depth of 60 feet was reached. A perforated galvanized-iron casing, about 20 gauge, was placed inside of the standard wrought-iron pipe used in the sinking and then the wrought-iron pipe was pulled out, allowing the hole to cave to the galvanized casing. Inside the casing the induction pipe of 6-inch standard wrought-iron was placed, this extending to a depth of about 40 feet from the surface, and into this the 2-inch air pipe was turned with a Pohle end-piece upon it. The delivery, as noted in the photograph, is made by 6-inch 180° bends, discharging into a common conduit.

This concrete conduit was built on the ground on wooden frames, with a grade of about 2 inches in 100 feet. It is 3 feet by 2 feet 6 inches, with a practically semi-circular bottom and open at the top, as we find very little trouble from freezing, never having any very cold weather at Garden City.

The wells are worked by the air pipe which starts from the factory. The first fifteen wells are on an 8-inch air pipe, the next five on a 5-inch, the next five on another 5-inch, and the next five on a third 5-inch pipe. We have, therefore, four groups of wells, three of five each and one of fifteen, fed by independent pipes from the receiver. This enables us to cut the air off at the factory compressor, if we choose, and to alternate the wells.

The conduit delivers into a concrete tank sunk into the ground. It is 30 by 20 feet and 10 feet deep, the suctions of the factory pumps taking from this. The tank is more for a sand trap or settler than for storage, as for that purpose the capacity required would be prohibitive.

The delivery of the wells could not be computed, nor even very approximately guessed, in advance, so, to make sure, twenty-five were sunk, for the reason that when the sugar campaign is begun operations cannot be stopped or interfered with without serious loss.

It was actually found that eight wells would give the requisite supply of 4,000,000 gallons per twenty-four hours. The natural water level is 12 feet from the surface, and as the pumping starts in September, this level gradually recedes until in December it reaches the lowest point, 25 feet from the surface.

SCIENCE OF THE AIR IN RELATION TO VENTILATION*

By N. W. Hoskins.

Air is simply a mechanical mixture of certain gases which exist in a free state, and vary within very narrow limits, except in the case of aqueous vapor. One hundred volumes of pure air consist of:

Oxygen	20.66
Atmospheric nitrogen	77.90
Carbon dioxide	.04
Aqueous vapor	1.40

Ammonia, argon, ozone and other gases are sometimes present in small and variable proportions.

Oxygen is the most important constituent of the air, and the quantity present in pure air in any part of the world varies very slightly. It is only under exceptional circumstances that it exceeds 21 per cent or falls below 20 per cent. In its pure state it is a colorless gas without taste or smell, slightly heavier than air, having a specific gravity of 16 (air being 14.4) compared with hydrogen as unity, and it is a vigorous supporter of combustion.

Nitrogen appears to act as a diluter of the stronger gases, but it doubtless has its special functions higher than this. A lighted candle plunged into a jar of nitrogen is immediately extinguished. It is a colorless, inert gas, without taste or smell, and will not support animal life or combustion. It is not poisonous, and animals enclosed in a space containing nitrogen alone would die of suffocation from the want of oxygen. Carbon dioxide (CO_2), although present in such small quantities compared with the gases dealt with, is one of great importance with respect to ventilation. It cannot be considered as an impurity, as the most pure air always contains a small proportion, seldom less than 0.03 per cent. Pure CO_2, even up to 0.1 per cent (one part in 1,000 parts of air), is not harmful, and in mineral water factories the air is often found to contain this high percentage without any harmful effects on the work-people employed. A large quantity of this gas is given off from our bodies direct, and by respiration; it is also one of the products of combustion.

*Abstracted from proceedings of Royal Sanitary Institute, London.

Absolutely dry air is never found in Nature, and aqueous vapor must, therefore, be considered as an essential ingredient of atmospheric air. It is also a very important constituent, which varies very considerably under different conditions of temperature and pressure. Moisture is being continually added to the air by evaporation from the water on the earth's surface, and also by respiration and combustion.

[The air also is constantly giving up its moisture under certain conditions, and one of its most important functions is the conveyance and distribution of moisture over the surface of the earth.—*Ed. C. A.*]

The higher the temperature, the larger quantity of invisible moisture the air can retain. Air is said to be saturated when it contains the maximum quantity of vapor it is capable of holding. This matter relating to moisture is frequently overlooked in the ventilating of buildings, and especially so when the heating of a building is designed in conjunction with the ventilating. Dry air is a bad conductor of heat, and therefore tends to prevent the escape of warmth from the body. In a room in which the air has a humidity of 30 per cent and a temperature of 70° Fahr., a person will feel perceptibly colder than in a room the air of which has 60 degrees of humidity and a temperature of 60° Fahr. By adding moisture, therefore, a room may at times be brought under more comfortable conditions at a less expense than by the consumption of fuel.

TABLE OF SATURATION UNDER DIFFERENT TEMPERATURES. BAROMETER 30 INCHES.

Temp. F.°	Weight of vapor in grains per cubic foot.	Temp. F.°	Weight of vapor in grains per cubic foot.
30	1.97	65	6.81
32	2.13	70	8.01
35	2.39	75	9.39
40	2.86	80	10.98
45	3.44	85	12.78
50	4.10	90	14.85
55	4.87	95	17.18
60	5.77	100	19.84

A trace of ammonia is usually found in town air, and is probably entirely due to the decay of nitrogenous animal and vegetable substances. It is a transparent gas with a very pungent peculiar odor; it will not support combustion, and is only feebly combustible. Ammonia is dissolved by water with avidity, a pint of water at 32° Fahr. absorbing as much as 23 cubic feet of the gas. Probably, therefore, the whole of the ammonia is cleared from the air during a shower of rain.

Ozone is a colorless gas of peculiarly unpleasant odor. Outside of the laboratory it is found only in open country and sea air. It is chiefly remarkable on account of its oxidizing power, and plays an important part in removing organic impurities from the air. Ozone is really a condensed form of oxygen, one molecule of the gas containing three atoms, whereas one molecule of oxygen contains only two atoms. Air charged with ozone has an irritating effect on the respiratory organs. The gas may be prepared experimentally by passing an electric current through pure dry oxygen. Little is known of the circumstances under which it is produced in nature. It is, however, intimately related with the development of atmospheric electricity.

The air of buildings and confined spaces is rendered impure by extracting the oxygen, which supports animal life and combustion, and by adding to it CO_2 and other deleterious substances. Large quantities of oxygen are required to support animal life, and in return CO_2, with other impurities, are continually being thrown off.

Although gases are of different densities, they have the power, when brought in contact, of intimately mixing together. This important property is termed the diffusion of gases, and has an important bearing upon the air of buildings, which is kept pure to a large extent by diffusion. Gases diffuse in the inverse ratio of the square root of their densities. The lighter the gas, the more quickly does it diffuse. Diffusion of gases takes place also, to a less extent, without being in actual contact. The materials used for constructing the walls of buildings permit the air to pass through more or less rapidly to diffuse with the outer air. The spontaneous mixing of gases is caused by their particles being always in rapid motion. A very small quantity of coal gas is soon detected in a building, owing to the power of diffusion. Gaseous impurities which leave our bodies at a higher temperature than that of the surrounding air quickly diffuse and become diluted, but in crowded buildings, and even in dense crowds in the open air, the impurities are often produced at a greater speed than the rate of diffusion.

In dealing with the density of gases, we must not overlook the importance of the varying changes brought about by moisture. The

density of the air varies with respect to the amount of moisture it contains. The density of a mixture of gases will be equal to the mean of its constituents, and the density of air is superior to that of water vapor in the ratio of 14.4 : 9. Therefore, *moist air will be lighter,* bulk for bulk, according to its hygrometric condition, and consequently *moist air tends to rise as warm air does.*

The old standard of purity, as laid down by Dr. De Chaumont, is that the air of a room should not contain more than 0.02 per cent of CO_2 in excess of the external atmosphere. This standard is advocated by most authorities, although considered by some to be rather stringent. On an average, we breathe at the rate of sixteen respirations a minute, inhaling about 30 cubic inches at each breath, therefore $(16 \times 60 \times 30 \div 1728) = 16$ cubic feet of air per hour is exhaled, of which 4 per cent, or 0.6 cubic feet, is CO_2. To maintain Dr. De Chaumont's standard of purity each person must be supplied with 3,000 cubic feet of fresh air per hour, and if the air of a room is completely changed three times in one hour, each person should be supplied with 1,000 cubic feet of air space. Dr. Galton says that 1.5 per cent of CO_2 present in the air will produce headache, and as anything below 0.1 per cent appears to have no detrimental effect on health, it would appear that the percentage of permissible impurity might well be raised to 0.1 per cent; this would bring the practice of the engineer more in keeping with the medical theory.

There is no simple and reliable test for determining the amount of organic impurities which may be present in the air. The quantity of carbon dioxide in a given volume of air may be ascertained by several methods, and as this gas bears a constant relation to the amount of organic impurities, it is usually taken as an indicator. It is well known that the air of an unventilated room which has been occupied by several persons for a considerable time will have a peculiarly unpleasant odor, which is due to the organic matters given off from the lungs and bodies. The following is a method sometimes adopted for estimating the amount of CO_2 in the air: Collect samples of the air for testing in four bottles, having a capacity of 4, 8, 16 and 32 ounces, respectively. The bottles must be clean and dry, and provided with rubber stoppers. A 1-ounce bottle of fresh lime-water is now carefully poured into each of the four samples, and the stoppers replaced. Agitate the lime-water for about three minutes, and observe the change in color of the lime-water added in each case. Should the lime-water in all four bottles show a milky appearance, it indicates that the samples contain above 2 per cent of CO_2. Should the liquid in the three larger bottles become milky, and the 4-ounce bottle remain clear, the sample contains approximately 1.4 per cent. A milky tinge in the 16-ounce and 32-ounce bottles only indicates 1 per cent, and should the liquid in the 32-ounce bottle only appear milky, the amount of CO_2 in the sample would be 0.06 per cent. No trace of color in any of the four bottles would indicate that the air was pure.

HOW PNEUMATIC TIRES DESTROY THE ROADS

A writer in *The Engineer,* London, writes as follows concerning the destructive action of the pneumatic tires of heavy automobiles:

"Living as I do close to the main road from Chichester to Worthing, I had ample opportunity of watching the action of fast and large cars last year during Goodwood week. The large fast cars might be said to be followed by a rain of small stones or coarse sand, and by the evening of Cup Day—Thursday—*the road was more like a sea beach than a main road.* I frequently examined a piece of road after the passage of several large cars, and I invariably found that, whereas the road was compressed and the stones crushed down by a farm cart, with a motor car the stones were lifted, in some cases to a considerable depth.

"The action of a pneumatic tired wheel takes two forms: (*a*) The load on the wheel tends to bed—*i. e.,* to press down a stone more firmly. The maximum load cannot, however, be applied more than momentarily owing to the shape of the wheel, and with fast-running cars, the pressure being applied for such a short time, the stone resists movement by its inertia. (*b*) Owing to the compression of the tire, the tire can act as a 'sucker,' and, therefore, clings to the stone before action (*a*) is at its maximum, and the stone, if small, is rolled out of its bed by its connection with a moving wheel and either thrown off behind or left in place as a 'loose' stone. Unless the stone is held in place by an active force, such as being keyed in with others, or being made practically

encastré with cement nothing will stand under fast-running pneumatic-tired wheels but heavy blocks of stone. A floated surface to an underbed of rough concrete will be liable to destruction by 'rolling out' in the same way that two metal plates soldered together can be separated by rolling out—*i. e.*, by stretching one plate unequally to the other. Ultimate separation is certain in course of time. The time required depends only on the quality of workmanship and solder.

1903, after much experimenting, Messrs. Pilkington evolved a compound-pneumatic hammer, which showed a considerable economy in the consumption of air compared with those of the high-pressure type in which separate charges of air are used for raising the tup and for striking the blow. The latter system involved the application of air under high pressure on a small piston in the lower of two vertical cylinders to strike the blow, the air after doing its work being then exhausted to

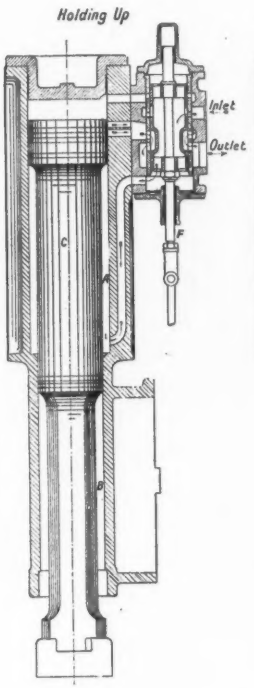

FIG. 1.

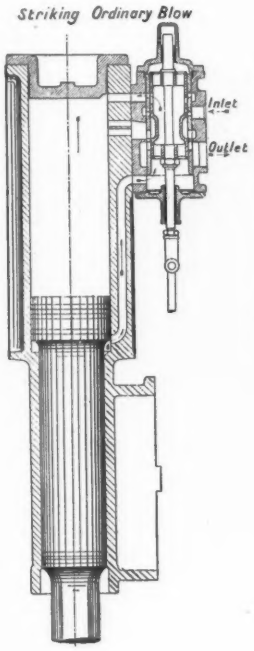

FIG. 2.

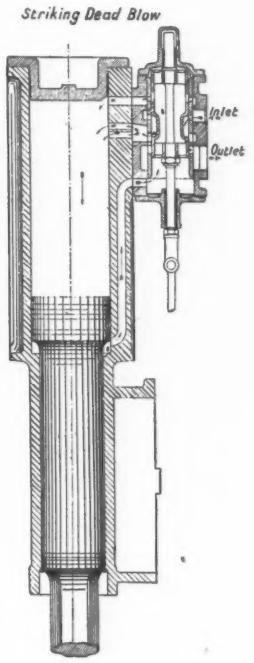

FIG. 3.

COMPOUND PNEUMATIC HAMMER

Although recent years have witnessed a great extension in the employment of pneumatic pressure in engineering workshops, for heavy hammer work such as is met with in large smiths' shops for forging operations, the steam hammer has not been superseded to any very considerable extent. The use of high air pressure for the operation of hand tools of the light percussive type is tending to familiarize works managers with the cleanliness and the "handiness" of pneumatic power which must end in a great development in its uses. In

a low-pressure receiver which was maintained at 30-40 pounds pressure from the first stage of a compressor. The low-pressure air thus bottled up was next admitted under a large piston to raise the tup, and to expel the air from the lower cylinder. This cycle necessitated the lower cylinder and stuffing-box being split on the longitudinal center line, which was found objectionable from a constructional point of view, and involved the use of an inaccessible stuffing-box round the rod between the lifting and striking pistons. Moreover, breakages of the piston rod due to the weight of the large piston setting up stresses in the rod at

the same moment of impact were not unknown. We give a sectional illustration of this older type of hammer in Figure 4, from which these points will be seen, and it will also be observed that the air was exhausted to the atmosphere at considerable pressure, meaning a loss of residual energy which the firm has now found a means of overcoming, as will be seen from the accompanying illustrations and dia-

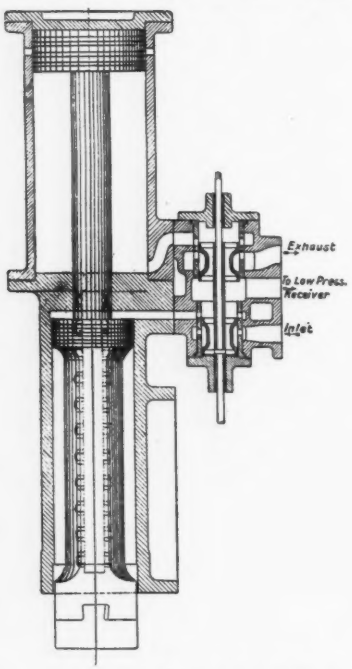

FIG. 4. OLD TYPE OF HAMMER.

FIG. 5. N. S. K. PNEUMATIC HAMMER.

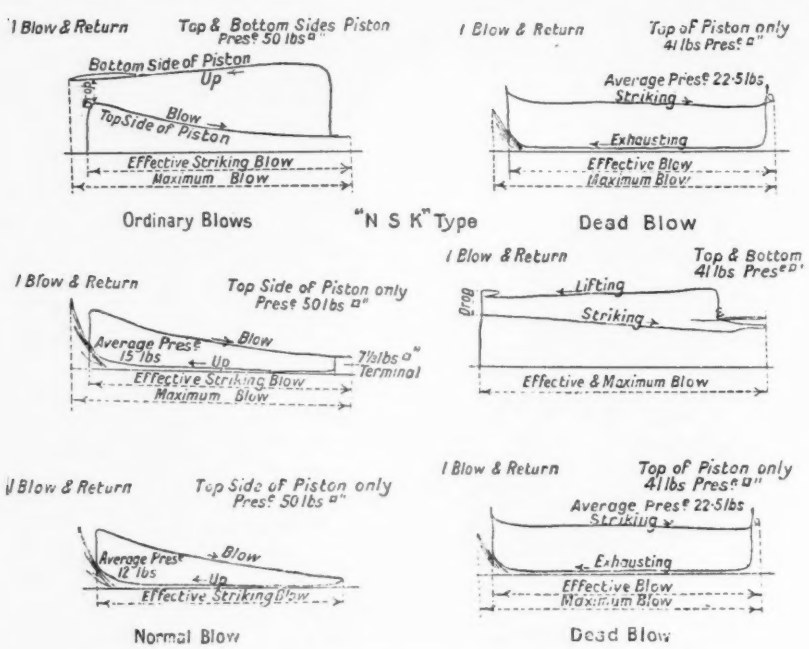

FIG. 6. INDICATOR DIAGRAMS FROM COMPOUND AIR HAMMER.

grams relating to the new "N. S. K." compound hammer.

A general view of one of a batch of seventeen of these hammers, which the firm of Peter

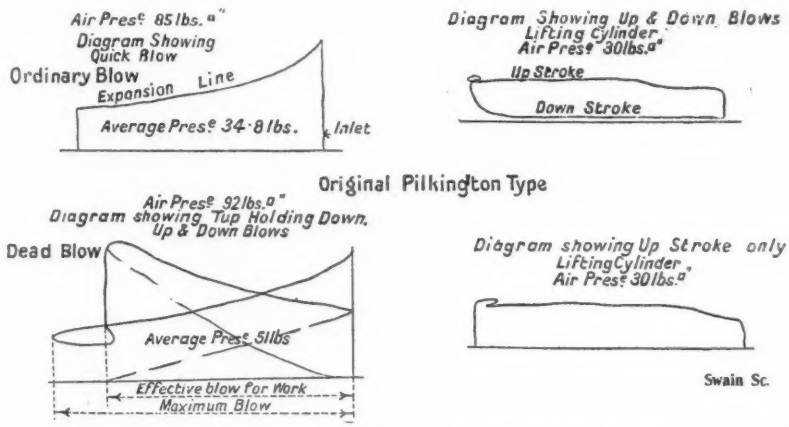
Air Press 85 lbs. a"
Diagram Showing Quick Blow
Ordinary Blow
Expansion Line
Average Press 34·8 lbs.
Inlet
Diagram Showing Up & Down Blows Lifting Cylinder. Air Press 30 lbs. a"
Up Stroke
Down Stroke
Original Pilkington Type
Air Press 92 lbs. a"
Diagram showing Tup Holding Down. Up & Down Blows
Dead Blow
Average Press 51 lbs
Effective blow for Work
Maximum Blow
Diagram showing Up Stroke only Lifting Cylinder. Air Press 30 lbs. a"
Swain Sc.

FIG. 7. INDICATOR DIAGRAMS FROM PILKINGTON HAMMER.

Pilkington, Limited, Bamber Bridge, is building for Messrs. Harland & Wolff, is shown in Figure 5, and in Figures 1, 2 and 3 are given sectional illustrations of the hammer, showing the tup and valves in their different relative positions. Figure 1 shows the holding-up position; Figure 2, the position of parts when striking an ordinary blow; and Figure 3, the positions of the valve and tup when making a dead blow. The tup, piston and jaws for securing the pallett are forged from a solid steel ingot, and the section of the tup is uniform throughout, while the cylindrical portion of the tup is almost entirely contained in the guiding cylinder when the blow is struck. As will be seen from the sectional drawings, there are two cylinders, A and B, the upper one, A, being the working cylinder, and the lower being used as the guide only. The upper end, C, of the tup working in the uppermost cylinder, A, is in the form of a differential piston. High-pressure air is admitted in the direction of the arrows, Figure 1, when raising the tup only, and this same air on being exhausted is expanded on the top side of the piston for striking ordinary blows, the path of the air being shown in Figure 2. If, however, a very heavy or stamping blow be required the operator can utilize the full air pressure in the compressor on the top of the piston in addition to that discharged from beneath the piston, the valves being constructed with two sets of ports, as shown.

The construction of the hammers is very simple, the operating valve being cylindrical, of cast iron, with suitable ports, working in a cast-iron liner. The valve is controlled by a hand lever actuating the valve spindle, F, in the same manner as that of a steam hammer, and its action is very sensitive. We have witnessed the operation of a N. S. K. hammer that has been in use for about fifteen months,

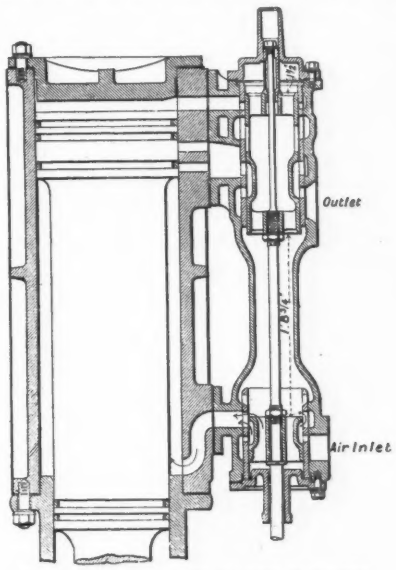

FIG. 8. CHEST FOR LARGE HAMMER.

the tup of which was arrested in any desired position, showing no leakage. A brief study of the sectional drawings will serve to illustrate the fact that owing to the difference in the areas of the annular ring below the piston,

Ordinary Blows.

	Original Pilkington type.		"N.S.K." type.	
	Formula.	Data.	Formula	Data.
Weight of tup..	7 cwt. 1 qr. 12 lb. =	824 lb.	8 cwt. 2 qr. × 112 lb =	952 lb.
Ft.-lbs. of energy due to tup falling 2ft. ..	824	1648	952 × 2 =	1904 lb.
Area of striking cylinder	Net sq. in.	58 sq. in.	Net sq. in.	95 sq. in.
Working pressure per square inch	Gauge	85 lb. per sq. in.	Gauge	50 lb. per sq. in.
Average pressure acting on striking piston	—	34·8 lb. per sq. in.	—	15 lb. per sq. in.
Ft.-lbs. of energy imparted to tup by air pressure	area pres. ft. $58 \times 34{\cdot}8 \times 2$ =	4036	area pres. ft. $95 \times 15 \times 2$ =	2850
Total energy imparted to tup by air pressure and gravity	1648 + 4036 =	5684 ft.-lb.	1904 + 2850 =	4754 ft.-lb.
Velocity of tup at point of contact ..	$\frac{5684}{824} = 6{\cdot}89 = \frac{V^2}{64{\cdot}4}$ $V = \sqrt{6{\cdot}89 \times 64{\cdot}4}$ = 21·06ft. per sec.		$\frac{4754}{952} = 4{\cdot}991 = \frac{V^2}{64{\cdot}4}$ $V = \sqrt{64{\cdot}4 \times 4{\cdot}991}$ = 17·9ft. per sec.	
Terminal pressure per square inch	Gauge	24 lb. per sq. in.	Gauge	7½ lb. per sq. in.
Cubic feet of free air discharged from low-pressure cylinder	$\frac{117{\cdot}6 \times 2 \times 39}{144 \times 15}$ =	4·205	$\frac{143{\cdot}14 \times 22\frac{1}{2} \times 2}{144 \times 15}$ =	3
Horse-power required to give 100 blows per minute	4·2 × 20 =	84	11·9 × 3 =	35·7
Horse-power corrected for equal work ..	—	84	$\frac{35{\cdot}7 \times 5684}{4754}$ =	42·66
Excess of power required by old system to do equal work as compared with new	$\frac{84}{42{\cdot}66}$ =	96·9 per cent.	—	—

FIG, 9. TABLE OF TESTS OF COMPOUND HAMMERS—ORDINARY BLOWS.

and that of the top of the piston, the air which has been used to raise the tup will be expanded to nearly four times its initial volume, and will be finally exhausted at about atmospheric pressure by the raising of the tup again.

We are enabled to give in tabular form some interesting details of tests made with the N. S. K. hammer, and the older Pilkington hammer, which show very clearly the saving in power effected by the former. In the first

Dead Blows.

	Original Pilkington type.		"N.S.K." type.	
	Formula.	Data.	Formula.	Data.
Weight of tup..	7 cwt. 1 qr. 12 lb. =	824 lb.	8 cwt. 2 qr. × 112 lb. =	952 lb.
Ft.-lbs. of energy due to tup falling 2ft. ..	824 × 2 =	1648	952 × 2 =	1904
Area of striking cylinder	Net sq. in.	58 sq. in.	Net sq. in.	95 sq. in.
Working pressure per square inch	Gauge	92 lb.	Gauge	41 lb.
Average pressure acting on striking piston	—	51 lb. per sq. in.	—	22·5 lb. per sq. in
Ft.-lbs. of energy imparted to tup by air pressure	area pres. ft. $58 \times 51 \times 2$ =	5916	area pres. ft. $95 \times 22\frac{1}{2} \times 2$ =	4275
Total energy imparted to tup by air pressure and gravity	1648 + 5916 =	7564 ft.-lb.	1904 + 4275 =	6179 ft.-lb.
Velocity of tup at point of contact ..	$\frac{7564}{824} = 9{\cdot}179 = \frac{V^2}{64{\cdot}4}$ $V = \sqrt{9{\cdot}179 \times 64{\cdot}4}$ = 24·3ft. per sec.		$\frac{6179}{952} = 6{\cdot}49 = \frac{V^2}{64{\cdot}4}$ $V = \sqrt{6{\cdot}49 \times 64{\cdot}4}$ = 20·4ft. per sec.	
Terminal pressure per square inch	Gauge	28 lb.	Gauge	22·5 lb.
Cubic feet of free air discharged from low-pressure cylinder	$\frac{117{\cdot}6 \times 2 \times 41}{144 \times 15}$ =	4·46	$\frac{143{\cdot}14 \times 37\frac{1}{2} \times 2}{144 \times 15}$ =	5
Horse-power required to give 100 blows per minute	4·46 × 21 =	93·6	5 × 10·6 =	53
Horse-power corrected for equal work ..		93·6	$\frac{53 \times 7564}{6179}$ =	64·8
Excess of power required by old system to do equal work as compared with new	$\frac{93{\cdot}6}{64{\cdot}8}$	44·4 per cent.	—	—

FIG. IO. TABLE OF TESTS OF COMPOUND HAMMERS—DEAD BLOWS.

table the figures are given for ordinary blows, and it will be noticed that the hammers under test are of different capacities. It will be observed that the terminal pressure of the new hammer is only 7½ pounds per square inch, compared with 24 pounds in the case of the older form, and also that the saving of power due to the further utilization of the air in the acceleration of the tup, when corrected to represent hammers of equal capacity, is nearly one-half. In the second table, for dead blows, it will be observed, notwithstanding the admission of live air on top of the piston, in addition to that from the bottom, that there is still a large economy effected by the new type of hammer. The diagrams—Figures 6 and 7—taken during the above tests are full of interest and speak for themselves.

The hammers are substantially constructed, have few wearing surfaces, and are well lubricated, while their method of operation is simple. Any weight of blow, from light to full normal, dead or holding-down blows, can be given by the movement of the lever. When the latter is released, the tup rises and remains in its highest position.

Figure 8 shows in section a hammer with an alternative form of valve chest. This design is used for heavier types of hammer.—*The Engineer,* London.

THE REACH OF SCIENTIFIC SPECULATION

In a recent address at Lehigh University John A. Brashear gave the following illustration of the minuteness of the atom:

"If you fill a tiny vessel, one centimeter cube, with hydrogen corpuscles, you can place therein, in round numbers, five hundred and twenty-five octillions (525,000,000,000,000,000,000,000,000,000) of them. If these corpuscles are allowed to run out of the vessel at the rate of 1,000 per second it will require seventeen quintillions (17,000,000,000,000,000,000) of years to empty it. Such a computation seems almost like trifling with science, indeed apparently trifling with the human intellect; but it is with these subtle theories that our physicists are wrestling, delving into the innermost chamber of the infinitely minute to build for us, upon the most stable foundation, the macrocosm of a universe."

OPERATING RECIPROCATING STEAM PUMPS BY THE DENSE-AIR SYSTEM

By Snowden B. Redfield.

From time to time I have had occasion to figure upon various methods of pumping water by means of compressed air, and a detailed study of the Dense-Air System of operating reciprocating steam pumps has developed much that should be of interest to those using compressed air.

By the Dense-Air system is meant that method of operating which comprises an air compressor delivering air at high pressure to some machine, such as the reciprocating steam pump, which after the air has done its work, exhausts it into a closed piping system leading back to the compressor intake, the pressure in this closed exhaust pipe being kept at some figure above, and usually considerably above, that of the atmosphere. It is well known that by this method of operation there is a considerable gain in economy, and the purpose of this article is to show, in a simple way, under what conditions this economy is obtained and what its value is.

A number of curves have been plotted which show the corresponding results of operation by various methods of Dense-Air application, compared with compressed air operation with ordinary atmospheric pump exhaust and compressor intake. Before examining these curves in detail a few words as to the cause of the increased efficiency by this system of operation will serve to make the matter clearer. Gauge pressures only are used.

Figure 1 shows a theoretical combined indicator card for ordinary straight compound air operation with 100 pounds compressor discharge pressure and atmospheric intake. Figure 2 represents Dense-Air operation with 150 pounds compressor discharge pressure and 50 pounds intake. The latter system of operation involves only single-stage compression, because the ratio of compression is only 2.54, as compared with 7.58 for the atmospheric system. The range of pressures, or the difference between the discharge pressure and the intake pressure, is the same in both cases, namely, 100 pounds, and it will be shown that the mean effective pressure in the pump cylinder to be operated is also the same in both cases. This small ratio of compression in the Dense-Air system, with a given difference of

pressures, is the cause of the increased economy of the latter.

In Figure 1 the length, A G, is supposed to represent a piston displacement volume of 10 cubic feet. With a cylinder ratio of 2.8 : 1, the length of the line, B K, will represent the volume of air discharged into the intercooler with adiabatic compression. This volume will

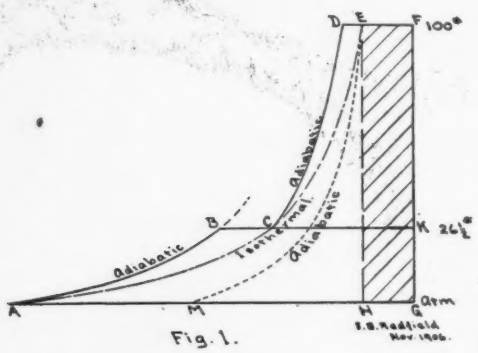

Fig. 1.

be 4.82 cubic feet. After intercooling, this length will be reduced to C K, or the volume will be reduced to 3.57 cubic feet. At this point the air is supposed to have been cooled to the initial temperature of the intake to the low-pressure cylinder, and this is the volume which enters the high-pressure cylinder. Again compressing adiabatically, at 100 pounds, the compressed air will have a volume of 1.72 cubic feet, represented by the length, D F. Aftercooling, or radiation, in the pipe line reduces this volume to E F, or 1.28 cubic feet, by the time the air enters the actuating cylinder of the pump. This is, of course, the same as the volume obtained by compressing up the isothermal line, A C E, and the air is again at intake temperature.

Assuming that the pump cylinder is to operate without cut-off, and assuming also that there is no loss of pressure in the pipe line, the length, E F, will represent the volume of air admitted to the pump cylinder at 100 pounds. At the end of the pump stroke release will take place and the pressure will drop down the line, E H, to atmosphere. On the back stroke the air remaining in the pump cylinder is exhausted along the line, H G, into the atmosphere, and at the end of the stroke a new admission of air takes place and the pressure rises up the line, G F. By this it is seen that the rectangular shaded diagram, F E H G, can represent the indicator diagram of the air cylinder of the pump, and the area of this diagram will represent the useful work done by the air in this cylinder.

It will be noted that with this rectangular diagram the mean effective pressure of the air exerted on the pump piston is 100 pounds per square inch, or the same as the difference between the discharge and intake pressures of the compressor. The area of this card, or the work done on this pump piston, will be equal to the total mean effective pressure times the volume swept through by the piston. This with 1.28 cubic feet of compressed air, as shown above, will be $100 \times 144 \times 1.28 = 18{,}430$ foot-pounds. If this work is done in one minute it will be equivalent to 18,430 divided by 33,000, or .558 indicated horse-power. This power has been developed in the actuating cylinder of the pump by what was originally 10 cubic feet of free air admitted to the compressor cylinders in one minute. To compress 10 cubic feet of free air per minute by compound adiabatic compression to 100 pounds there will be required 1.535 indicated horse-power in the compressor cylinders.

The efficiency of the system is then: Power developed in pump cylinder divided by power required in compressor cylinders, or .558

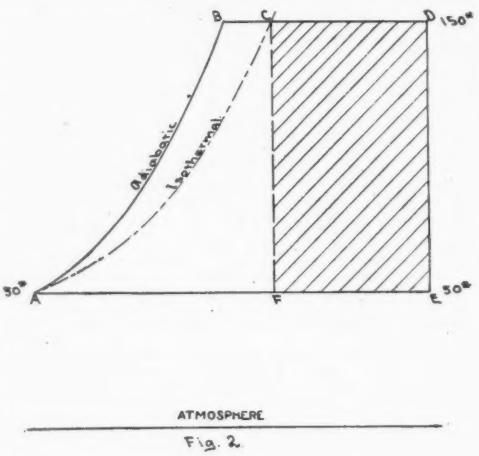

Fig. 2.

divided by 1.535, which equals 36.4 per cent.

Turning to Figure 2, which represents operation by the Dense-Air system, the line, A E, represents as before 10 cubic feet of piston displacement, but in this case at 50 pounds gauge pressure. Compressing adiabatically in a single-stage to 150 pounds gauge pressure, gives the volume 5.15 cubic feet of compressed air, represented by the line, B D. This volume cooled to intake temperature would be

3.94 cubic feet, shown by line, C D. This volume of cold compressed air passes to the actuating cylinder of the pump and, as before, there will be admission, release and exhaust in the pump cylinder, forming a rectangular indicator card, but with 150 pounds initial pressure and 50 pounds exhaust pressure. This indicator card is represented by the figure, D C F E. The work done by this rectangular card with 3.94 cubic feet of compressed air admitted to the pump cylinder, as shown, and with a mean effective pressure of 100 pounds per square inch, as given by this rectangular indicator card, will be $100 \times 144 \times 3.94$, which equals 56,700 foot-pounds. Assuming this work to be done in one minute, this would represent

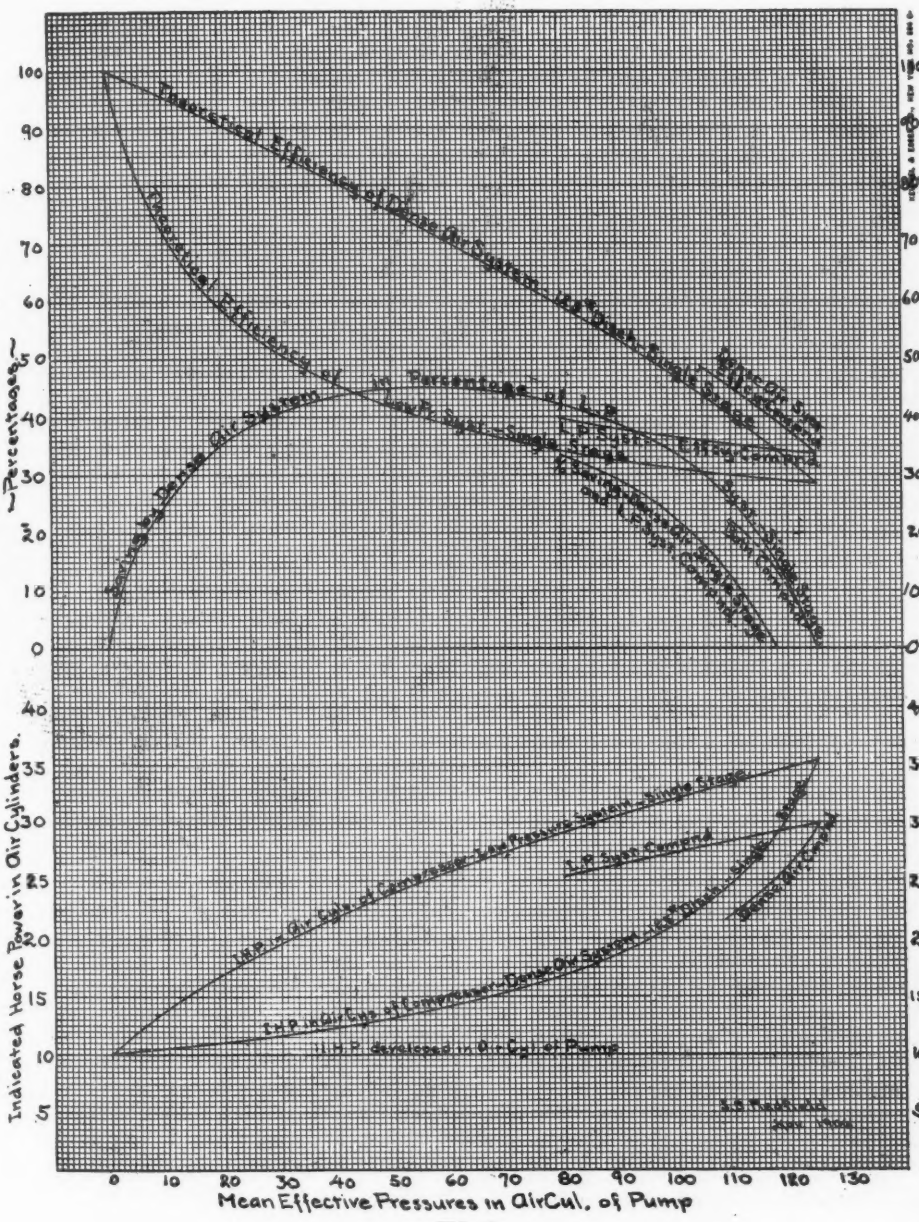

FIG. 3.

1.72 indicated horse-power in the air cylinder of the pump. To compress adiabatically in one stage 10 cubic feet piston displacement of free air per minute from 50 to 150 pounds requires 3.04 indicated horse-power in the air cylinder of the compressor. These figures, then, give the efficiency of this Dense-Air system equal to: Horse-power developed in pump cylinder divided by horse-power of air compressor cylinders, or 1.72 divided by 3.04, which equals 56.5 per cent.

With the straight-air operation, having compressor intake and pump exhaust at atmosphere, there was obtained an efficiency of 36.4 per cent, and with the Dense-Air system it has been shown that the efficiency is 56.5 per cent; thus the gain in efficiency is apparent.

It will at once appear that the gain in efficiency will depend upon the pressures and the range of pressures chosen, and it is obvious that the smaller the ratio of compression the greater the economy. It naturally follows that the advantage lies with high initial pressure and correspondingly high back pressure, giving a small ratio of compression.

As before said, all the foregoing calculations are based on a mean effective pressure of 100 pounds per square inch in actuating cylinder of pump, the mean effective pressure being the same as the difference between the maximum and minimum pressures, or the pressure range of the cycle. In actual practice a maximum pressure of 125 pounds in the pump cylinder is about the upper limit to which the manufacturers desire to go without special construction and extra expense. For this reason it will be well to confine further arguments to this practical limit.

It is obvious that with a given size of pump cylinder the work performed depends upon the mean effective pressure in that cylinder. This being the case, the comparison of results for any two systems of operation should be made on a basis of the same mean effective pressure in the two cases. For the purpose of showing the results of operation with various mean effective pressures, a number of curves are given (Figure 3), which are calculated on a basis of developing 10 indicated horse-power in the actuating cylinder of the pump.

These curves are entirely theoretical, being based upon adiabatic compression in the compressor cylinders, with no losses due to friction, clearance, throttling or pressure drop. These losses would, however, occur in both systems, and for a basis of general comparison, the theoretical curves will serve a very good purpose.

In the case of the Dense-Air system the maximum pressure is always kept at 125 pounds gauge and the lower pressure is set to give the desired pressure range. For the low-pressure system, the maximum pressure is set to give the desired pressure range, while the minimum pressure is always atmospheric. As an example, suppose it is desired to obtain a mean effective pressure of 50 pounds per square inch, as shown by the rectangular indicator card of the pump cylinder. In the Dense-Air system, the maximum pressure is to be kept at 125 pounds gauge, so the minimum pressure must be 75 pounds gauge, in order to give the desired range of 50 pounds. For the low-pressure system, the minimum pressure must be kept at atmosphere, so the maximum pressure must then be 50 pounds gauge. Thus, these two cases have the same pressure range, or 50 pounds mean effective pressure in the pump cylinder, and the various theoretical results obtained by the two systems are clearly shown and compared by the curves for this, and for other mean effective pressures from zero to 125 pounds. In all cases the pump cylinder is here supposed to be made the correct size to develop the 10 indicated horse-power with the mean effective pressure assumed.

In these curves horizontal distances represent mean effective pressure in pounds per square inch in the actuating cylinder of the pump, while vertical distances represent respectively, beginning at the bottom: indicated horse-power in air cylinders of compressor required to develop 10 indicated horse-power in actuating cylinder of pump; saving of power by Dense-Air system in percentage of power required by low-pressure system, and, finally, the efficiencies of the two systems, or ratio of indicated horse-power developed in actuating cylinder of pump to indicated horse-power required in air cylinders of compressor. The various curves are so marked as to be readily understood.

Examining the lower, or indicated horse-power curves, it will be noted that the curves for the Dense-Air system and the low-pressure system come together at two points. First, at the point of 125 pounds mean effective pressure we have for both the Dense-Air system and the low-pressure systems simply straight com-

pression from atmosphere to 125 pounds. The curves show that to develop 10 indicated horse-power in the pump cylinder requires 35.3 indicated horse-power to be developed in the air cylinders of the compressor by either system by single-stage compression, and 29.8 indicated horse-power by compound compression. At this point the percentage saving of the Dense-Air system over the low-pressure system is, of course, nothing, as is shown by the curves of saving. Also at this point the efficiency of the two systems is the same, and is 28.2 per cent for single-stage and 33.6 per cent for compound compression, and is shown by the fact that the efficiency curves meet at this point.

The other point at which the indicated horse-power curves come together is at the point of zero mean effective pressure. This is a point where there is a very curious state of affairs, which can be viewed only from the theoretical standpoint. To properly examine the conditions here obtaining it is necessary to take the view of mathematicians on the subject of the value of Zero. To quote the expression of professors of mathematics—"Zero is not *nothing;* it is an infinitely small quantity, just disappearing!" This being the mathematician's viewpoint, it follows that zero multiplied by infinity, has a finite value.

Now to return to the curves:

At the point of zero mean effective pressure there is then an infinitely small mean effective pressure acting on the pump piston. It follows that in order to perform 10 horse-power of work it is necessary to have an infinitely large piston area, or cylinder volume. It is now perhaps possible to imagine a compressor indicator card with an infinitesimal height and infinite length. Being only infinitesimally high, the curve of adiabatic compression is infinitely short, and consequently the area under this curve is infinitely small. As the area under this curve represents the work lost in heat, this loss must be infinitely small. If the losses are then infinitely small, the amount of work done in the pump must be equal to the work done in the compressor, with the exception of this infinitely small loss. This means that the efficiency of the system must be infinitely near 100 per cent. The foregoing results hold both for the low-pressure system and for the Dense-Air system. In the former system the compressor intake is only an infinitely small amount greater than this, so that the range of pressures, or the mean effective pressure in the pump cylinder, is infinitely small, or zero. In the Dense-Air system the discharge pressure is, as before, 125 pounds and the compressor intake is only an infinitely small amount less than this, so that the mean effective pressure is again infinitely small, or zero, and in both cases there is an efficiency of 100 per cent, as shown by the above reasoning.

Referring to the curves it will then be noted that at the point of zero mean effective pressure in the pump cylinder, the curves of indicated horse-power of compressor come together for both systems at the point of 10 indicated horse-power, also the curve of saving passes through zero, and the curves of efficiency for the two systems meet at the point of 100 per cent.

Curves are given showing comparison between operation by both systems, single-stage; both systems, compound, and low-pressure system, compound, with Dense-Air system, single-stage. The compounding has been limited to those pressure ranges where it would be advantageous from a commercial standpoint, and to the compressor cylinders only. The pump is always single-stage.

After this careful study of the Dense-Air system, from a theoretical standpoint, it will be interesting to make some calculations based on what might be expected in actual practice, taking into account all losses due to friction, throttling, pressure drop in air line and clearance. For this purpose let the problem be as follows:

Quantity of water to be lifted, 400 gallons per minute.
Lift, 830 feet.

This lift, counting in 10 per cent pipe friction, would amount to a water pressure of about 400 pounds at the pump. Glancing at the curves for saving of power by the Dense-Air system, it will be noted that the maximum saving with 125 pounds maximum air pressure at pump, is obtained with a mean effective pressure of between 50 and 60 pounds in the air cylinder of the pump. Bearing this in mind, it is advisable to use such a cylinder ratio as to obtain this mean effective pressure. Of course, a lower mean effective pressure would give a higher efficiency, as shown by the curve, but the size of the air cylinder of the pump must be kept within practical limits.

This mean effective pressure gives a very satisfactory cylinder size, and at the same time gives the greatest saving over the straight-air system.

For the purpose of doing this pumping with a commercial size of pump, assume one of duplex construction, having two air cylinders 32-inch diameter by 36-inch stroke, and two water cylinders, 10-inch diameter by 36-inch stroke. Allowing 10 per cent slip of water, a piston speed of 55 feet per minute for each side of the pump would handle the required 400 gallons per minute. This amounts to a piston speed of 110 feet per minute for a simple pump. With the water pressure given above and with the given cylinder ratio, the mean effective pressure required in the air cylinder to drive this pump, including 80 per cent mechanical efficiency between the two cylinders, would be 48.7 pounds per square inch. Assuming a diagram factor of 90 per cent, due to throttling and the rounding of the indicator card as obtained in actual practice, the theoretical mean effective pressure required to drive this pump will then be 54 pounds. Let the air pressure at the pump throttle be 125 pounds. In order to obtain 54 pounds theoretical mean effective pressure, the back pressure of the pump will have to be 71 pounds. Allowing 5 pounds drop in the pipe line from the compressor to the pump and 6 pounds drop from the pump back to the compressor intake, the pressures at the compressor will be 65 pounds intake and 130 pounds discharge. There is then a range of pressure of 65 pounds at the compressor and 54 pounds at the pump. With 110 feet piston speed, the volume of the air cylinders of the pump will be 612 cubic feet per minute. This volume filled with air at 125 pounds amounts to 5,820 cubic feet of free air per minute. This quantity of air returned to the compressor at 65 pounds amounts to 1,073 cubic feet per minute. Assuming the clearance of the pump cylinders to be 10 per cent, and bearing in mind that this clearance space is filled at each revolution of the pump with air at 125 pounds and expanded down to 71 pounds at release, there is a quantity of air used by this clearance equal to 225 cubic feet of free air per minute. This returned to the compressor at 65 pounds is equivalent to 42 cubic feet. This added to the amount usefully used in the pump cylinder and the total increased by about 3½ per cent for piston leakage, would amount to 1,155 cubic feet of compressed air at 65 pounds returned to the compressor cylinders.

Assuming about 93 per cent volumetric efficiency for the compressor, there will then be required a piston displacement equivalent to 1,240 cubic feet per minute. To compress 1,155 cubic feet of air from 65 pounds to 130 pounds by single-stage compression would require about 295 indicated horse-power in the air cylinders of the compressor. The work done in the air cylinders of the pump is equal to the mean effective pressure multiplied by the volume swept through by the piston. With 49 pounds actual mean effective pressure in the air cylinders of the pump and with 110 feet piston speed per minute, there will be developed 131 indicated horse-power in these cylinders. What might be termed the thermal efficiency, then, is the indicated horse-power of the air cylinders of the pump, divided by the indicated horse-power of the compressor. This, then, is 131 divided by 295, which equals 44.4 per cent. This figure is what corresponds to the figures given by the curves of efficiency, with the exception that in this case all probable losses have been taken into consideration, whereas the curves are purely theoretical.

The theoretical efficiency, according to the curves, for the conditions outlined for this problem, is 76 per cent; 44.4 is about 59 per cent of this theoretical value. Under ordinary conditions it may be assumed that the actual efficiency to be expected from such a system as this is from 55 to 65 per cent of the efficiency which would be calculated from a strictly theoretical analysis.

Comparing the above problem with operation by straight low-pressure air, taking into account all losses as before, it would be possible to operate this pump with 54 pounds at the throttle and atmospheric exhaust. It is clear from the previous reasoning that this range of pressures would give the same mean effective pressure in the pump cylinder, namely, 54 pounds theoretical or 48.7 practical. Allowing 6 pounds drop in the pipe line, the compressor could discharge at 60 pounds, having atmospheric intake. As before, the piston displacement of the pump cylinders would be 612 cubic feet per minute. This volume filled with air at 54 pounds would amount to 2,860 cubic feet of free air usefully used per minute. With 10 per cent clearance and 54 pounds initial pressure and 2 pounds back pressure, the

clearance would consume about 216 cubic feet of free air per minute. This added to the previous amount, plus about 3½ per cent for piston leakage gives a total quantity of free air required to operate this pump of 3,196 cubic feet per minute. With 92 per cent volumetric efficiency of compressor this would require a compressor piston displacement of 3,480 cubic feet per minute. To compress 3,196 cubic feet of free air per minute to 60 pounds, single-stage, would require about 473 indicated horse-power in the air cylinders of the compressor. As before, the indicated horse-power of the pump cylinders would be 131, and the efficiency of the system is, therefore, 131 divided by 473, which equals 27.7 per cent; thus it is evident that the efficiency by the Dense-Air system even from a practical standpoint is much greater than that by straight low-pressure air operation. To carry this problem still further and to make a commercial comparison, it is advisable to calculate the steam which would be used to drive this pump if used directly in the pump cylinder and the steam which would be used by an air compressor to do this work—295 indicated horse-power in the air cylinders of the compressor would amount to about 330 indicated horse-power in the steam cylinders. Assuming 100 pounds steam pressure, compound, noncondensing, a rate of about 22 pounds of steam per indicated horse-power per hour could be expected. This compressor would then use 7,260 pounds of steam per hour. In a reciprocating pump of the kind under consideration the steam rate would be at least 75 pounds per indicated horse-power per hour. The indicated horse-power of the actuating cylinders of this pump was found to be 131. At 75 pounds steam rate this would be equivalent to 9,820 pounds of steam per hour. The result, then, is that the air compressor will use 7,260 pounds of steam per hour, as opposed to 9,820 pounds of steam used directly on the pump. This means that the compressor will use 74 per cent of the steam which would be used for direct steam operation, and still perform the same amount of work and lift the same quantity of water.

Returning to operation by low-pressure air: It was found that the air cylinders of the compressor would develop 473 indicated horse-power in order to perform 131 indicated horse-power in the pump cylinders; 473 indicated horse-power in the air cylinders is equivalent to about 525 indicated horse-power in the steam cylinders of a steam-driven compressor. With the same steam rate as before—that is, 22 pounds per indicated horse-power per hour—this compressor would require 11,560 pounds of steam per hour. This quantity of steam is, of course, greater than that required to operate the pump by steam used directly in the cylinders, so there would have to be some reason other than economy only for operating this pump by low-pressure air.

This saving of fuel is a very attractive argument, but it is not advisable to jump to too hasty conclusions as to the use of the Dense-Air system for other purposes than the operating of reciprocating steam pumps. With such a machine as the pump considered, which would operate with fair regularity, and which would not have to be continually moved about as a rock drill would have to be, the conditions are practically ideal. When it comes to operating an engine having cut-off and expansion, by Dense Air, the results to be obtained depend upon the cut-off, the release pressure, the minimum allowable temperature and the mean effective pressure, which all again depend upon each other. The combined effect of all these items complicates the problem beyond the possibilities of this article. It is sufficient to say, however, that with early cut-off, little or nothing can be gained by Dense-Air. The gain is greater the later the cut-off, and the later the cut-off the nearer the case approaches that of the pump already discussed. It would hardly seem that the gain to be obtained by Dense-Air operation of expansive engines in actual practice would warrant the additional complication, except under extraordinary circumstances.

For rock drills operated by the Dense-Air system there is a great disadvantage, in that it necessitates two lines of piping. As the piping of a rock drill plant is usually very temporary, and, even with the best of care, liable to excessive leakage, this double line of piping, with the increased pressures, makes this condition worse than ever. Also the necessity of having two sets of piping to connect up, handle and move from place to place, makes the use of Dense Air with rock drills more of a disadvantage than otherwise, and with pneumatic tools it is, of course, out of the question.

Even when operating a reciprocating pump, which it has been shown is the most desirable

machine to operate with the Dense-Air system, there is the very great disadvantage that a separate compressor termed the "booster" is necessary in order to make up the leakages in the air line, as, even with the most careful attention, some leakage is bound to occur and this must be made up in order to keep the pressures at the proper points. The horse-power of this compressor should, of course, be added to the horse-power of the main compressor and this will reduce the efficiency of the system to a greater or less extent, depending upon the amount of leakage.

From the foregoing argument it now appears that before using the Dense-Air system it would be most advisable to give careful consideration to all the advantages and disadvantages as herein outlined, and any particular case must be settled on the conditions to be met in that case and conclusions drawn must be based upon these conditions. As with most things of merit, if the conditions are right, and proper use is made of it, a very considerable gain can actually be obtained by the use of the Dense-Air system.

THE ROCK DRILL AND THE AIR COMPRESSOR IN COPPER MINING

As the average yield of copper ores is only 2 to 3 per cent of metal, some ores being handled with profit which yield but 1 per cent of metal, the importance of economy in all the operations and agencies is evident. With such low-grade ore a cent more or less in the cost of getting out and treating a hundredweight of ore would mean an equal difference of cost per pound of metal produced. Copper mines therefore have always been in the lead in the development and adoption of the most advanced mechanical facilities, and it is no wonder that they have been notorious scrappers all along of costly machinery as improvements have successively become possible.

Copper mining is credited with the first successful use of steam engines, of iron skips and cages, iron and steel cables, high explosives and air-driven rock drills. The first steam engine, Savery's, was erected in a copper mine in Cornwall, England, two centuries ago. Newcomen's engine, which was an improvement upon this, was also in a Cornish copper mine, and Watt's first engine was for mine pumping at Chacewater, Cornwall.

The copper mines of Lake Superior and of Montana have practically killed the mines of Cornwall, and now these latter lead the mines of the world in the depths of their openings and in both the capacity and the economy of their hoisting, pumping and air-compressing machinery. The first copper mining in the Lake Superior region was in 1844. Calumet & Hecla was opened in 1866. In 1880 the Butte deposits were discovered. Anaconda mine was first opened as a silver mine.

The first Rand drill was placed in the Calumet & Hecla in 1878, and at the beginning it had to make a desperate fight for existence. The mining costs in the decade between 1881 and 1891, during which these drills got under full headway showed changes as follows: Stoping per fathom, 1881, $14.35; 1891, $4.33; drifting, 1881, $10.08; 1891, $4.92. High explosives must be given part of the credit. In Calumet & Hecla for the seven years after the introduction of the Rand drills the following was their record: Sinking shafts and winzes, 20,715 feet; drifting veins and cross-cuts, 78,660 feet; stoping, 83,997 fathoms; or nearly 4 miles of shafts and 15 miles of drifts. The rock thus removed amounted to 291,333 cubic yards in drifts and 671,976 cubic yards in stopes. The shops of the company now dress 50 tons of drill steels per day.

The Calumet & Hecla built for itself the biggest air compressors in the world; one Leavitt compressor having a nominal capacity of operating 500 drills though never actually running over 300. Some of these early compressors had their mission in showing what is *not* best in air-compressing practice. The wet compression principle is now practically abandoned, and, also, the building of air compressors, as with the building of pumps, of machine tools and other lines of machinery, has gone into the hands of concerns which make it their specialty, and the air compressors of the Rand or of the Ingersoll-Sergeant Companies are found in practically all of the copper mines of America and a list of them is impossible in the present publication.

The following Ingersoll compressors are in the service of a single mining company in Montana, only the diameters of the first air cylinders being given: two 60-inch, one 50¼-inch, one 38¼-inch, one 36¼-inch, one 30¼-inch duplex, three 24¼-inch duplex, three 22¼-inch duplex, two 24¼-inch, one 37¼-inch four-stage for charging mine locomotives.

These fifteen compressors have a combined capacity of 60,000 cubic feet of free air per minute, and all except one or two of the oldest of them are high-class machines, embodying the devices which promise the best economy both in the development of the power from the steam and in the application of the power to the compression of the air and the delivery of it in condition most fit for use, these characteristics being common to nearly all of the numerous air compressors employed in this vast industry.

COST OF ROCK DRILLING IN SWEDISH MINES

"The use of boring machines, which was at first confined to rising in the back of levels, has during the past ten years been extended to cutting plat, shaft sinking and driving the ends. They have shown their advantages, even at a higher price per unit of depth of hole bored. In the Lomberg mining district machines weighing 88 to 110 pounds, with piston of 2-inch diameter, have bored 24.67 feet per shift of eight hours, yielding 4.34 tons of rock per metre bored, against 3.45 tons with hand boring (1.32 against 1.05 ton per foot), notwithstanding that the effect of the explosive was diminished from 1.59 tons per kilogram to 10.83 tons (7.21 to 9.49 tons per pound.). The cost per ton of spoil was 10.4 cents, including miners' and fitters' wages, sharpening drills, repairs and powder, but nothing for redemption. Hand boring costs only 10 cents per ton, but the machine did the work of more men. In the same district the cost of driving levels of 43 square feet area has been $3.75 per lineal foot by machine boring, including the same items as above, as against $4.08 by hand; or, say, for levels 6 feet wide by 6 feet high, $3.20 per foot forward by machine, against $3.44 by hand. Here the chief gain is that the ends are driven more than twice as fast by machine.

"Pneumatic drills are at present maintaining their superiority over electric, which only under exceptional circumstances can compete with them. At Gräugesberg the author's experience has been that although electric drills take less power, they are not cheaper in working, because what is gained in power is lost in diminished efficiency, and in greater wear and tear. With electric drills the depth bored per core (shift?) has run up to 22.31 feet in ore and 19.39 feet in country, with an average depth of 8.53 feet per hole. With pneumatic drills the corresponding figures have been 32.15 feet and 25.65 feet or roundly 8.2 feet more per core (shift?) with the advantage of better ventilation underground.

"In the Rand and Ingersoll machines the piston and drill are in one piece, so that they move together. For some years trials have deen made, at Gräugesberg and several other mines in Sweden of an American water jet machine (probably the Leyner drill), in which the piston is separate from the drill and strikes it with great rapidity. Water is ejected by compressed air through the hole, and as the drill always strikes on a clean surface, the effect is considerably increased, while the difficulty with the dust is obviated. At Gräugesberg this machine has bored 9,648 feet in 290 cores (shifts?) or 33.3 feet per core, where the Rand machine did no more than 25.82 feet. But the difficulty is to get the steel to stand; the American drills were useless in the hard stone of the Swedish mines. The Storfers works have now succeeded in making a thoroughly good drill steel.

"The bore holes can be drilled by machine both deeper and larger than by hand with augmented effect. In open quarrying at Gräugesberg the quantity of stone loosened per metre (3.28 feet) bored has been increased from 4.57 to 1.2 tons (1.39 to 3.41 tons per foot), and in hard compact rock to 18.7 tons (5.7 tons per foot), with holes averaging 9.25 feet deep and 1 inch diameter at bottom. At Kiruna, where the holes are bored twice as deep and 1.6 inches in diameter, the quantity per metre bored has averaged in three months 102.3 tons (31.2 tons per foot) and in some places has gone up to 180 tons (55 tons per foot).

"With the larger and more effective bore holes the rock is blasted in large blocks, which have then to be drilled and blasted smaller for removal. For this purpose portable mechanical jumpers—pneumatic percussion drills held in the hand and requiring no stand—have been devised during 1905 by the Ingersoll firm and by the Atlas Company, Stockholm, both of which have been tried at Gräugesberg on four different kinds of rock. The author considers that hand boring ought speedily to disappear from mines equipped with compressed air."—*Teknish Tidskirft,* Stockholm.

SUBMERGED ROCK CRUSHING

The Lobnitz chiseling machine for submarine rock excavation, like many other devices, has its special field of employment in which it is highly successful. It is being used with satisfaction in harbor improvement work at Blyth, near the northeast corner of England. Drilling and blasting with subsequent dredging were first employed, 150,000 cubic yards of rock having been taken out in this way. A chiseler plant consists of a steel barge carrying at one end shear-legs from which is suspended a steel ram weighing 15 tons. It is about 45 feet long and 18 inches in diameter, with a renewable hard conical point. The ram has a drop of 8 feet and an average of eight or nine blows is sufficient to penetrate or crush the sandstone rock about 3 feet, so that 2½ feet at a time can be dredged. One machine working night and day with average stoppages breaks up about 900 cubic yards per week at a cost of $0.18 per cubic yard. Contingent and incidental expenses for operation and maintenance make the final cost $0.29. Drilling and blasting cost about $0.72 per cubic yard and the rock was left in a somewhat less favorable shape for removal. The drilled and blasted rock cost $0.76 per cubic yard to dredge, while the chiseled rock cost $0.66.

POWER ECONOMY IN RETURN AIR

In learning to use compressed air economically the same course has been traversed as in the use of steam, although the lesson having been first and completely learned with steam as the motor fluid, it might have been expected that once thus learned it might have been much more quickly appropriated by the users of the air. Steam was first used to fill a cylinder or other chamber, at full pressure, and to do what work it was capable of at that pressure, and then it was discharged at that full pressure into the atmosphere, or into the condenser. Steam so used was the passive transmitter of the pressure in the boiler, and itself really did no work. The use of steam expansively, allowing its elasticity materially to augment the total of work accomplished, was a later achievement.

So when compressed air is applied, in what has been the usual way, to the operating of the familiar apparatus, to the rock drill, the direct air hoist, or even in driving a steam pump, the air, which is used at full pressure and is then discharged, actually does no work with which it may itself be credited. A passive column of it is simply pushed along by a force behind it, either actually by the compressor itself, or by the slight expansion of the large body of air in the receiver and mains, and this notwithstanding the fact that the air, each individual cylinderful of it, is capable of doing work by its expansion all the way down to the pressure of the atmosphere into which it is finally discharged.

We may believe that the great gains accomplished by the use of steam expansively were not ignored by the earlier users of compressed air, the simple fact being that while they would gladly have saved the wasted power, they did not at first, nor for a long time, see the way to do it. Compressed air, for instance, has been many times employed for forcing water to higher levels. With a chamber full of water, and a discharge pipe leading up to the height at which it was desired to deliver the water, air of sufficient pressure would be admitted to the chamber above the water, and the air would drive the water up the pipe. When the operation was completed the chamber would be full of compressed air, and then the question would come up as to what could possibly be done with this air except to discharge it into the atmosphere so that the chamber might fill with water again, and as no answer was forthcoming the air would be discharged and all its expansive force would be wasted, this practice ruling from the very earliest use of compressed air until quite recently, when a device, which in principle is extremely simple, solved the perplexing problem. The return-air pumping system, instead of discharging the air at its full pressure, pipes it back to the intake of the air compressor; in its reëxpansion this air helps the compressor piston to do its work, and this help reduces to that extent the power-cost of compressing the air to the pressure required for forcing the water.

The electric air rock drill, another quite recent invention, is a return-air apparatus which accomplishes results still more astonishing in the way of power economy in the use of compressed air. It transforms the extravagant wastefulness of the familiar air-driven rock drill into the completest economy in the transmission and application of power, under the most difficult and exacting condi-

tions. In this case not only is the elastic force of the air entirely utilized, but there are no losses in the filling of clearances, and the cushioning of the piston is only a carrying over of force from one stroke to the next.

It is evident, therefore, that the development of efficiency in the use of compressed air has attained a point impossible with steam, since practically all the energy contained in the exhaust is returned to the compressor.—*Cassier's Magazine.*

PIT SINKING THROUGH FROZEN QUICKSAND

Mr. E. Seymour Wood recently read a paper before the North of England Institution of Mining Engineers describing a remarkable feat of shaft sinking through quicksand by the aid of the freezing process. The coal mine is located close to the east coast of the county of Durham, which lies south of Newcastle and the Tyne.

The difficulties of sinking shafts in the East Durham district arises from the occurance of magnesian limestone and underlying yellow sands, the latter being usually found as a quicksand, and both of these strata contain large quantities of water. At Dawdon, the magnesian limestone is 356 feet thick, and the yellow sand 92 feet thick. The limestone as is usual, is full of gullets, giving off large quantities of water. Some of these gullets are connected with the sea, the water issuing from them being salt. The question was therefore considered whether to erect additional pumping plant or to carry out the sinking of the shafts through the sands in a frozen state. It was decided to adopt the freezing process. Accordingly, the shafts, each enclosed in a wooden shed, were handed over to the contractors, Messrs. Gebhardt and Koenig, Nordhausen, in April, 1903. This firm undertook the freezing of the ground through which the two shafts were to be sunk, and also the adjoining ground, to such an extent as to enable the owners of the colliery to carry out their sinking arrangements without the air of pumps, until each shaft was sunk to a depth of 484 feet from the surface, and to establish and maintain a solid wall of ice around each shaft, so long as should be necessary for the purpose of sinking. Twenty-eight bore holes were marked off in a circle 30 feet in diameter surrounding the shafts and were bored to a depth of 484 feet. After the whole of the freezing tubes were inserted, they were connected to the inner and outer collectors, for the circulation of brine. The length of time required to form the ice wall at the Castlereagh shaft was 185 days. The ice wall was maintained 353 days, and the total time of freezing was 538 days. The sand was struck at a depth of 371 feet and found to be frozen hard. In the shaft bottom the frozen sand was so hard that blasting had to be continued throughout the deposit. The temperature of the frozen sand at the bottom of the pit was —14C, (+6F.) The thawing of the frozen ground was accomplished by circulating warm brine through the freezing tubes. Once through the frozen sand the progress of the operations was very brisk.

A CORNWALL ROCK DRILL INVENTOR

Of inventions and inventors there is no end. The number of rock drills is legion, and the claims put forward on their behalf are still more so. The other day I was asked to visit the house of an old miner, who had manufactured a rock drill of his own, worked by hand or other power. The machine was, of course, in an incipient stage, and being built on wooden supports was perhaps hardly up to the stability required for continuous practical working; but it contained a number of ingenious ideas, including even a water spray arrangement of original design, the water being fed from a bucket placed anywhere handy. Strange to say, the old man had never seen a real rock drill at work, although he had been a miner all his life. On one occasion, indeed, in passing through Camborne, he had seen one in the window of a firm there, but his wife, who was with him, he mildly complained, was in too great haste to allow him to study its details. Certainly, however, his own design was in no way similar to any other known drill. The earnestness and enthusiasm with which the old man would set the machine working, punching holes in large stones, spraying them profusely with water the while, was—well, interesting. He was very anxious that someone should take up his invention and patent it. Undoubtedly he had exercised great ingenuity, but unfortunately the result would not, of course, for a moment compare with the magnificent machines now turned out by Cornish and other firms. Finally, he let out that

he would like someone to purchase the machine from him, as he had an idea for a still better one in his head! Still, I think it would have broken his heart if he had parted with it.

COMPRESSED AIR DRAFT FOR HEATING RIVETS

It has often been said that the effect of compressed air draft when used in connection with oil fuel without a fire wall in the furnace, produces not only a hard rivet but a hard, thick scale on the same. As regards compressed air draft, causing rivets to become hard, it is only an assumption, and right here is the place to ask, "Who can positively say that it does?" To the writer's knowledge no man has ever made scientific tests to determine the actual amount of hardness produced in steel rivets through heating them by means of liquid fuel and compressed air, and I would ask, would it not be reasonable to believe that the furnace is always hot enough to absorb all of the moisture contained in compressed air long before it reaches the rivets. If it did not what harm could it possibly do to the body of the rivet? I will venture to say none, from the very fact that any kind of heating of mild steel, such as rivets are made from, tends to anneal it. As rivets are made from mild steel by a similar process to that of our steel boiler plate, and we all know that we can heat this red hot, then quench it in cold water and bend it double; pray, tell us, what harm a little moisture in a furnace could possibly do to a steel rivet? In the writer's opinion, very little, if any.

Then, again, let us take a broad view of it: Suppose that if it did have a tendency to make the rivet harder this would be in its favor, as rivets are subject to a shearing strain, and if they become harder after they are driven it would only increase the shearing strength. To make them soft enough to drive it would only be necessary to bring them to a heat that would be best suited for the kind of riveting to be done, whether it be hand, snap, pneumatic, hydro-pneumatic, compression or hydraulic. Therefore, the effect of heat upon steel rivets, aided by forced draft, which includes compressed air, is of so little consequence that it ought not be given consideration by practical men, and the pages of technical books are too valuable to record items of so little value and consequence.—T. C. Best, in *The Boiler Maker.*

DETERMINING THE COMPOSITION OF INDUSTRIAL GASES

Professor F. Haber has devised a method for ascertaining approximately the composition of a gas by means of its index of refraction. This, he finds, can be obtained with great accuracy by observing the displacement of the image which occurs on looking with a telescope at a distant object through a glass prism into which the gas is led. He uses an instrument made by Zeiss, of Jena, consisting of a prism telescope, a glass prism for the gas or air, and a mirror. The observer looks, not at a distant object, but at a luminous spot situated in the telescope itself. On looking into the instrument one sees a dark shadow, which falls upon a scale in a position corresponding to the composition of the gas in the prism. The method is simple, and has the advantage that the refractive index as compared with air, of a sample of gas, remains the same, provided any changes of temperature and pressure affect equally the sample and the air under comparison. If chimney gases be led through the prism, an increase of 0.9 per cent in the carbon dioxide causes the shadow to be displaced one division on the scale. The instrument is sensitive to 0.0000003 in the index of refraction, which corresponds to a change of 0.2 to 0.25 per cent of carbon dioxide in chimney gases. Methane (marsh gas), hydrogen, hydrochloric acid, and hydrocyanic acid can be determined in air with the same delicacy. In the case of acetylene or sulphuretted hydrogen the exactitude is twice as great; for sulphur dioxide two and one-half times as great, and for the vapors of pentane and benzine nearly ten times as great. Its sensitiveness has been proved quite satisfactory.—*Engineering.*

VACUUM MAKES A RECORD

A vacuum pressure of 400 pounds to the square inch drew practically every drop of blood from the body of W. D. Hunter, an engineer in one of the Chicago packing houses, and was the cause of a most unusual form of death. Hunter had gone to repair a tank used in the refrigerating process, had evidently slipped and one leg was drawn into the pipe, where it was held fast by the enormous suction. When discovered by his helper only a few minutes after the accident, the body was shriveled, absolutely white and cold. —*Popular Mechanics.*

COMPRESSED AIR
AND EVERYTHING PNEUMATIC

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EVERYTHING PNEUMATIC

On another page of our present issue Mr. Tecumseh Swift calls attention to the simple fact that all the air we know of or have anything to do with is compressed air, and that therefore the title of our publication tacitly compels us to deal more or less with all air, whatever its pressure at any given time and whether or not its pressure has been increased by the mechanical reduction of its volume in passing through an air compressor of any type.

There can be no question as to the correctness of this dictum. All air *is* compressed. That is, all air, even free air, as we conveniently call it, is under more or less pressure. No air has any absolutely constant pressure. All air is constantly being compressed or re-expanded, and all the phenomena accompanying these operations are constantly recurring. With the changes of pressure are interdependent changes of volume, of temperature, of electric condition, all inviting study, with no promise of our ever reaching the limits of acquirable knowledge or of its practicable applicability in any direction.

The more that air is studied—always compressed air—the more wonderful is it shown to be. All organic life is dependent upon it, and this in more than one particular. Air is a chief instrument in maintaining temperatures within the possibilities of animal and vegetable existence; air is the chief agency in conveying and circulating the waters of the earth; air distributes its elementary gases, the one to sustain animal and the other vegetable life; air supports combustion, and all our "artificial" light and heat and power are derived from it; air assists in the diffusion of the illuminating and vivifying rays of the sun; air is a function in the operation of the electrical forces or nerve energies of the earth. None knows all of any of these things. These we can all be studying together, accumulating and contributing attainable knowledge each for all and all for each. We accept the hint of Mr. Tecumseh Swift and everything pertaining to air, and especially to the work it may be made to do for us, will be within our legitimate field. All who have anything new to tell of what air has done, is doing, or may be made to do, are invited to help us. We want Everything Pneumatic.

COMPRESSED AIR FOR LARGE HAMMERS

The valuable article which in the present issue we reprint from *The Engineer,* London, describing a compressed air operated hammer built by the Messrs. Pilkington, contains one sentence which should be specially noted: "The use of high air pressure for the operating of hand tools of the light percussion type is tending to familiarize works managers with the cleanliness and handiness of pneumatic power which must end in a great development in its uses." This is the constant story of the growing employment of compressed air in manufacturing. Continually one thing leads to another, or, rather, to two or three others, as Herbert Spencer says every cause is followed by more than one effect. The use of air for large hammers makes its way in the beginning by its handiness and readiness rather than by its absolute economy at the coal pile, but when air is used in sufficient quantity to make the saving of it eminently worth while then the economies are looked into and developed.

It is stated that seventeen of these hammers are being built for the Harland & Wolff shipyard where the air already is employed so extensively for the smaller pneumatic tools, riveters, chippers, caulkers, reamers, drills, etc. The air supply was there before the big air-operated hammers came, and now they are employed in such numbers that those which can show a saving in the use of air are chosen in preference to those original types which once satisfied if they only would go. The use of air thus developes the paradox that the more it is saved the more it is used. Where attention is given to the savings which are possible in the use of the air we may be very certain that the savings will be as sharply looked after in the compression and transmission of it, and the results cannot fail to be remunerative and gratifying.

TWO ENGINEERING RECORDS

Since the closing of our previous issue two notable events of interest to the entire engineering world call for mention. The first of these is the record-breaking, record-making trip of the new Cunard liner, Lusitania. Her achievement is the culmination of the labors of thousands of engineers, also of business organizers and pushers for a century, and it is impossible to assign the greatest credit to any one man, at least since Watt. All the world gets the benefit and all civilization shares the glory.

The second event, the fall of the Quebec bridge, it is sickening to think of. It is an item of the world's engineering record perhaps more exclusively than the other. We were expecting that here, too, would be an advanced record of successful achievement. Leading engineers planned the bridge, many engineers approved the plans, and if any did not approve or had fears for the strength or safety of the structure they were not heard of. Builders of long experience and with the most up-to-date facilities did the work. Presumably the best and most perfect materials were used, and tested, as far as the possibilities of testing extended. The production of the material was inspected and also its manipulation in the shop at every stage. The work was carefully planned in every detail, the erection as it proceeded was carefully noted and reported upon, the weather was not unpropitious, there was no high wind or earthquake shock, and before the erection was completed everything all at once fell straight down and four-score men were dashed to sudden death. The record is unique.

CORRESPONDENCE.

ALL AIR IS COMPRESSED AIR

Editor Compressed Air:

I have just been looking over two or three back numbers of COMPRESSED AIR and perhaps I may be permitted to say a word or two concerning my impressions. It seems to me that the publication has not fully realized its opportunity, and that on the other hand its readers have too tamely accepted it at its own valuation. While the restricted aim has been to deal only with the air which has passed through a compressor and been mechanically reduced in volume, the fact is that all the air with which we come in contact or concerning which we have any practical knowledge is compressed air. Some of it is compressed more and some of it less, but all is compressed by the weight of the air above it. If it were possible for us to ascend high enough we might reach the region of uncompressed air, air

which had no weight of other air above it, but I don't know how we would be able to determine when we arrived at the top of the sea of air or how we would discover the line of demarcation between it and perfect vacuum. They say that men have gone in search of the North Pole who would not have been able to recognize its location if they had reached it.

If we went downward instead of upward from what we may call the normal level of compressed air we certainly would find the additional compression of the air one of the principal facts to deal with. Some time ago some foreign engineer was planning to bore a shaft down say a dozen miles through the integument of Mother Earth to see what he would find which is at present unknown. The cutting of the rocks and their successive removal was the simplest part of the job. The prohibitive condition which he ran against was the air pressure to be encountered. Why, when he got down to the depth spoken of he would have a pressure of a hundred pounds or so, and the compressed air apparatus of the human body is not adapted to deal with that, so he would have had to have contrived air locks to keep the air out long before he reached the bottom of the hole, and he would be bothered all the while with the air leaking in as fast as he could pump it out, so that how far it would be possible to penetrate toward the center of the earth has not been settled to this day, and to a great extent on account of the indeterminability of the compressed air factor.

The fact is that we are born into compressed air. Our first breath of life and our last is of compressed air, and without air suitably compressed we could not live a minute. A publication, then, which proposes to treat of compressed air has all the human race for its prospective constituency, and it should not be satisfied until it, by deserving, has secured a considerable portion of the total of readers to which it is legitimately entitled. It is to be hoped that the conducters of COMPRESSED AIR will not let up in their endeavors to give us the latest and the completest information concerning the artificial compression of air and the various and widening employment of air so compressed, but it should remember that air so compressed is less than a drop in the bucket compared with the air which is compressed by gravity, that the latter is charged with the maintenance of life and the sustenance of every activity, that all our life long we may be hearing of its uses and its wonders, with still more continually before us yet unknown. The legitimate business of COMPRESSED AIR should be to deal with *Everything Pneumatic.*

TECUMSEH SWIFT.

QUESTIONS AND ANSWERS

It must be obvious that the Editor cannot undertake to answer questions by mail. Questions presumably of interest to readers will be answered here as far as possible, and such questions are invited.

W. M. S., Batson, Texas.—*Q.*: If a tank holding 100 cubic feet was filled with air to a gage pressure of 100 pounds and another tank of the same size was connected closely to it, a valve being opened and admitting air from the first into the second until the pressures and volumes were equal, would the second tank then have in it 50 per cent of the first one? That is to say, would it have 50 per cent of the original working energy? If not, where would the difference of energy go?

A.: Having 100 cubic feet of air at 100 pounds gage pressure, or $100 + 14.7 = 114.7$ pounds absolute pressure, the volume of free air contained in the first tank would be $114.7 \div 14.7 = 7.8 \times 100$, or 780 cubic feet. The contents of the second tank being 100 cubic feet of free air to begin with, the total free air contents of the two tanks will be $780 + 100 = 880$ cubic feet. The absolute pressure of the air when equalized in the two tanks, after the normal temperature is resumed, will be

$$200 : 800 :: 14.7 : 64.68,$$

and the gage pressure therefore will be $64.68 - 14.7 = 48.98$ pounds.

Now the question seems to be, if put into an approximately practical form: Will 200 cubic feet of air at 49.98 pounds, gage, be capable of doing as much work as 100 cubic feet at 100 pounds? Referring to Table VI., page 108, Richards' COMPRESSED AIR, we find that air at 100 pounds used in an engine, cut off at one-quarter stroke and expanding adiabatically down to 1.33 pounds, which is near enough to atmosphere, will have a mean effective pressure for the stroke of 44.19 pounds. Then with a piston area of 1 square foot and a stroke of 1 foot the work per stroke will be 44.19 foot-pounds, and as but ¼ cubic foot of air will

be used per stroke there will be $100 \div \frac{1}{4} = 400$ strokes of work, or $44.19 \times 400 = 17{,}676$ foot-pounds of work for the 100 cubic feet at 100 pounds.

From the same table VI., but on page 103, we find that air at 50 pounds cut off at three-eighths stroke will have practically the same pressure at the end of the stroke as in the previous case, 1.34 pounds, and will have a mean effective pressure for the whole stroke of 29.07 pounds. Then, with a piston area of 1 square foot and a stroke of 1 foot, as before, the work done per stroke will be 29.07 foot-pounds, and as but $\frac{3}{8}$ cubic foot of air will be used per stroke the total number of strokes will be $200 \div \frac{3}{8} = 533$ strokes of work, or $29.07 \times 533 = 15{,}494.31$ foot-pounds of work for the 200 cubic feet at 50 pounds. It would be a little less than this, as we find the pressure to be a little less than 50 pounds in the two tanks. The work done here is thus about 13 per cent less than that done by the 100 cubic feet at 100 pounds.

It is scarcely necessary to inquire here where the energy was dissipated. If the air at 100 pounds had been discharged into the atmosphere or allowed to expand all the way down to atmosphere, of course all the available energy would have been lost. The loss would have begun with the beginning of the re-expansion and some of the loss would therefore have occurred, as it did occur, before the pressure of 50 pounds was reached.

W. G. L., Los Angeles, Cal.—*Q.*: Can you tell us what the saving is, in percentage of efficiency, in returning the air to the inlet pipe of the compressor in place of exhausting into the atmosphere in using the displacement system of pumping by compressed air?

A.: It is understood that what is wanted is a comparison of the efficiency of a plain pneumatic displacement pump with that of a properly proportioned return-air pumping system, both working under similar conditions. It will be seen that in a question of this kind there are several particulars to be considered. The lift or head against which the water is pumped is important. Generally speaking, return-air pumps are not employed for lifts of less than 50 feet, because the percentage of loss in a plain displacement pump increases with the head against which the pump acts, or, in other words, the loss due to the escape of compressed air into the atmosphere where only low pressures are required is not so serious as it must be under higher lifts, the greater loss being because the air *is not used expansively.* As the loss in efficiency in using any plain displacement pump increases as the head, it follows that the percentage of gain in favor of a return-air system is greater when pumping against a head of 200 feet than it would be in lifting the water 100 feet.

The depth of water over the tanks (amount of submergence possible) or the suction lift necessary to draw the water into the tanks, if it is necessary to place the tanks above the water level, are conditions which modify the efficiency of a return-air system. This particular point may be illustrated by taking the following conditions: Lift of water, 150 feet; pipe volume, 0.4 of tank. Then with a suction lift of 10 feet the efficiency would be 43 per cent; with the tanks just covered, 48 per cent, and with a submergence of 10 feet, 51 per cent. Finally, the greatest loss in a return-air system is caused by the drop in pressure due to the expansion in the low-pressure pipe after switching; therefore, the ratio of volume of air pipe to volume of tank must be kept as low as possible.

To state something definite in the matter of relative efficiencies, the best we can do is to make a comparison, taking some common, ordinary case, say, a lift of 150 feet. The ultimate efficiency of a properly proportioned return-air system, measured from the indicated horse-power of the steam cylinder of the compressor to the net work in water lifted, will be from 50 to 55 per cent; and, as against this, the best efficiency of a plain displacement pump will be from 24 to 27 per cent.

THE MINE LOCOMOTIVE EXPLOSION

In our July issue we gave some account of the explosion of a compressed air locomotive with fatal results in Colliery No. 14 of the Pennsylvania Coal Company. We suggested that the initial cause of the explosion was the formation of an explosive mixture of air and oily vapor and then the ignition of the same caused by a sufficiently high temperature at some point.

The following letter, appearing originally in *Mines and Minerals,* offers additional suggestions in the same line, giving also a variety of valuable information concerning other acci-

dents of the same character. We print the letter in full:

"Regarding the explosion of the compressed-air locomotive, there is no doubt in my mind but that the compressed air contained in the tank had a sufficient admixture of an explosive nature to become detonated, and consequently would be so suddenly expanded by heat that safety valves or other vents would not even have time to respond or move from their seats before the tank was exploded. The volatile properties of the oil used in the compressor could furnish the necessary amount of carbon to form a combustible mixture in the pipes, as well as in the locomotive. We know of numerous instances where these explosions have occurred, but how the ignition or detonation of the gas occurs has never been explained, satisfactorily, at least.

"An air receiver exploded out in Oak Park, Ill., several years ago, and there was no fire anywhere near it at the time it occurred. Another explosion of this kind occurred at the power house at Quinnessec Falls, near Iron Mountain, Mich., where the air is compressed by water power, blowing up the receiver and setting the building on fire. There was no fire in the building at the time, no boiler being used. A similar accident occurred at the Lumaghi Coal Company's mine, near St. Louis, where a receiver, located in the mine, a long distance from the engine house, exploded. The explosion of the receiver in the compressor plant at Quinnessec Falls proves that it was accomplished by heat, as the combustible gas set the building on fire after the explosion. The duration of the flame would depend on the amount of carbon to a given quantity of air and seemingly there was a sufficient amount of it in this case to support the flame a sufficient length of time after the receiver exploded to set the building on fire.

"The receiver at Oak Park, of the Lumaghi Coal Company, and the pneumatic locomotive in the present instance did not show the presence of fire, but the percentage of carbon in the mixture was probably much less than in the Quinnessec compressor case, not even sufficient to support the flame after the explosion had occurred, yet sufficient to heat the mass of compressed air to a sufficiently high temperature to cause the tank to explode. While I am not in a position to prove it definitely, there is no doubt in my mind but that these explosions are caused by detonation, and not by direct ignition by fire.

"In all the above cases the fragments proved that explosions had taken place, inasmuch as the plates were shattered into, comparatively speaking, small and irregularly shaped pieces. If these receivers and tanks had become ruptured on account of the pressure being greater than the material could stand the pieces would be much larger and the receiver or tank would be ruptured in two or three places like a bursted boiler. With reference to mixtures of atmospheric air and gases and the duration of the flame after explosion, I will relate two cases that I had an opportunity to observe a few years ago.

"Several car loads of hay were maliciously ignited in the freight yards of the C., M. and St. P. R. R., a short distance from our works. On the adjoining track was located a large tank of crude petroleum. The heat from the burning hay heated the oil tank until the pressure became sufficiently great to partially rupture the top of the tank and blow the dome, located near the center of the tank, entirely off. The explosion of the heated liquid oil, of course, was instantaneous as soon as the rupture of the tank exposed it to the atmosphere. The explosion, however, only partially consumed the oil, but its force was sufficient to thoroughly diffuse or disseminate the entire mass. It shot into the air, I should say, about 1,000 feet. I know this from my personal observation, as I happened to see the occurrence, watching it from a safe distance. So much carbon was diffused through a small amount of atmospheric air that the combustion was only partially accomplished. Tongues of flame were shooting out from the huge black cloud considerable distances in all directions, proving that there was not a sufficient amount of oxygen in the atmosphere immediately surrounding the mass for the large amount of carbon contained in the diffused oil to cause instantaneous combustion. The mass continued to burn in the air more gradually than if the necessary amount of oxygen could be immediately transmitted to it by the circulation of the atmosphere through the combustible gas. It burned a sufficient length of time to ignite any inflammable material with which it came in contact, the action of the explosion being the same as in the case of the Quinnessec power house when the tank exploded, containing rich combustible gas.

"The second case was an explosion of gasoline, which, of course, is much lighter and much more volatile than the crude petroleum. It mingled with the atmosphere instantaneously. The explosion was as sudden and nearly as violent as the explosion of smokeless powder, neither smoke nor flame being visible.

"In the latter case there was nothing to indicate that any flame had been produced by the explosion, as nothing was blackened, or showed the effects of heat in any way. I am merely referring to these two instances to show that, while an air tank might be exploded without the fragments showing any evidence of heat or fire, as in the latter case, the former case showed plainly the presence of both. So that, if an air tank does explode without leaving behind any trace of heat or smoke, it does not necessarily imply that it was not an explosion due to heat.

"S. T. NELSON,
"Supt. Chicago Works, Sullivan Mach. Co."

TRADE PUBLICATIONS

Butt-Welding by the Thermit Process, Goldschmidt Thermit Company, 90 West street, New York; 12 pages, 6x9.—This pamphlet describes the process and the apparatus employed in the welding of pipes and rods, with price lists and other details.

Record of Recent Construction, No. 63, Baldwin Locomotive Works, Philadelphia; 32 pages, 6x9 inches.—The frontispiece shows the exhibit at the Jamestown Exposition and full page half-tones are given of 14 different types of locomotives with the principal dimensions of each in English and French.

Victor Air Compressor, Victor Electric Company, 55 Market Street, Chicago. This leaflet describes a small vertical electric-driven air compressor built by the company. The pistons are 2-inch diameter and 2½-inch stroke. The outfit is adapted to the use of physicians, dentists, air-brush artists, etc.

Tobin Bronze, Ansonia Brass and Copper Company, 99 John Street, New York; 40 pages, 4x7 inches, illustrated.—This publication contains a wide reach of information concerning the valuable material represented, with numerous testimonials of the highest character. The accounts given of the applications of Tobin Bronze in marine architecture and engineering are specially interesting.

Power Plant Equipment, Schuette and Koerting Company, Philadelphia; 24 pages, 11x8 inches.—Enumerating and illustrating the Koerting injector, the eductor condenser, the Koerting spray nozzles, automatic stop check valves, free exhaust valves, quick closing balanced trip valves and numerous other standard valves and devices manufactured by the company.

Economical Machinery for the Coal Mine, Ingersoll-Rand Company, 11 Broadway, New York; form 53A, 24 pages 3¼x5½, 15 half-tones.—This handy leaflet gives a variety of information concerning the various machines for the coal mine manufactured by this company. Ten entirely distinct lines of apparatus are treated of, all up-to-date and of the highest efficiency in their respective classes.

A Complete and Modern Line of Brass and Iron Specialties is shown in the Catalog of The William Powell Company, of Cincinnati. This catalog presents their line in a most complete and practical manner, giving dimensions of every article for which a dimension may be required, and explaining in detail the merits of their well-known specialties.

Gauges, Wells Bro.'s Company, Greenfield, Mass; 54 pages, 4⅞x7⅞ inches; numerous illustrations and tables.—The gauges and micrometers described are mostly for measuring screw-threads on pipes, bolts and nuts, etc. This class of tools, and these tools of this class, are doing much in the promotion of precise workmanship and the fixing of accurate standards, these particulars being paramount not only in the production of reliably interchangeable parts but also in reduction of cost of manufacture.

Technical Literature, which with its June issue completed its first half yearly volume, purposes to review and index the most important articles in the various technical publications, American and foreign, abstracting and reproducing the most prominent, suggestive and informing. Technical journals, books and proceedings are now so voluminous, and collectively so costly, that few have the means and still fewer the time to go through them, and yet a knowledge of them is very essential to the progressive man whatever his interests. *Technical Literature* is a careful and thorough collector and sifter, and is doing a work the results of which should not fail to be appreciated and appropriated.

QUICK WORK ON A BIG FLY WHEEL

The C. & G. Cooper Company of Mount Vernon, Ohio, have just completed the installation of a large flywheel for the Youngstown Iron and Steel Roofing Company, Youngstown, Ohio, in record time. The wheel was built to replace one which burst August 5th. This old wheel had been in service a great many years, and with the engine was built in Providence. The Youngstown Iron and Steel Roofing Company gave the order for the new wheel on August 9th, with the understanding that it was to be shipped in twenty-six days.

The wheel is 24 feet 8 inches in diameter and weighs 90,000 pounds. It was designed, cast, machined and shipped complete from the works of the C. & G. Cooper Company on August 31st, or in eighteen working days. This anticipated the promised delivery about five days. It was delivered to the roofing company Sunday, September 1st, erected and running by Tuesday, September 3d. The wheel is of the square-rim type, made in halves, and held together at the rim by double-headed, countersunk tees of fagoted iron, and at the hub by four 4-inch bolts, and also double-headed tees. The arms are oval shape, and ten in number. The joints of the wheel are fitted with 3-inch tool steel dowels, which serve the double purpose of insuring a true joint and resisting any centrifugal strains by the shearing strength of the pins.

NOTES

The interesting article in our September issue, "Recent Practice in Tunnel Driving," was condensed from an article in *Mine and Quarry*, and not in the publication to which we credited it.

The largest mine ever exploded in Europe was sprung recently nearly 5,000 feet above sea level. Eight tons of a special explosive, having a power equivalent to twenty-four tons of gunpowder, was employed, and the whole of the fore part of Mount Maggiore, near Carrara, consisting entirely of splendid white marble, was blown away. It is calculated that half a million tons of marble was displaced.

Practical use of air as an electrical insulator is made in a method patented by Prof. H. J. Ryan. The conductors have ordinary minor insulation and are inclosed in a compartment containing air sufficiently compressed to afford the requisite dielectric strength. It is estimated that at 588 pounds per square inch air should be as good as linseed oil bond paper; at 265 pounds as good as nicanite cloth, and at 118 pounds as good as melted paraffine.

The new coal shaft being opened at Atchison, Kan., is the deepest bituminous coal shaft in the United States. It works a coal vein at a depth of 1,126 feet. The hole was sunk with a diamond drill and the entire core, with the exception of some coal removed for analysis, is preserved at the State University. In all eighteen beds of coal were penetrated, and of this coal 2 feet is unquestionably workable. The total cost of drilling was about $4,700, roughly at $3.50 per foot.

The walls of the Acropolis at Baalbek are truly called Cyclopean. The famous Trilithon, the largest stones ever used in building, measure respectively 65, 64, and 63 feet in length, each block weighing about 750 tons. How these huge masses were accurately placed in position 20 feet above the ground is a problem which modern science, with all its appliances, leaves yet unsolved. Above them are the Arab fortifications. The quarries whence these gigantic materials were obtained are among the most interesting features of Baalbek. Here may still be seen the method of work of the ancient quarrymen, stones vertically hewn lying almost ready to the hand of the builder. One of these stones, to which the Arabs give the name of Hajar-el-Houbls, measures 69 feet in length, and weighs 915 tons. M. de Sauley calculates it would take the united efforts of 40,000 men to put this huge block in motion. This quarry is now used as a necropolis by the inhabitants of Baalbek.

At the north shaft of El Oro mine, Mexico, the discarded steam cylinders of the hoist, which is now operated by electric current, are used in a novel way for speed regulation. The new motor is a 120 horse-power variable speed induction unit coupled directly to the pinion shaft of the hoist. In lowering a cage down the shaft the pistons of the old engine are made to compress air in the cylinders so that

by opening or closing a valve a fine speed regulation may be obtained.

The French Government has approved the use of submarine signalling, and has ordered submarine signal bells actuated by pneumatic power to be placed at the ends of the piers at Calais, Boulogne, and Havre, and a submarine signal buoy to be placed for trial off Havre. A submarine signal bell has been fitted to the Sandette lightship, off Dunkirk, for some time. When these bells are working there will be practically a continuous system of submarine signals from Havre to the Elbe.

That remarkable instrument, the barometer, is subject to curious fluctuations, apart from the ordinary steady rise and fall, little undulations caused by sudden changes, and by such simple things as the presence of a cloud over the locality. These oscillations are so minute that nobody ever thought they could be indicated on a barograph—the chart which records the movements of the mercurial column. Nobody, that is to say, but Mr. Dines, who, at the instigation of Dr. Shaw, has invented a strange piece of mechanism, which actually does register these minute variations—the "embroidery of the barometric chart," as the director calls them—and so produce a microbarograph.

Rock breaking on the Suez Canal has been done since 1902 with Lobnitz chiseling machines having 13-ton rams. The average height of fall of these rams is from 5 to 10 feet. On the average 132 blows are delivered per hour of effective rock breaking, but as the passage of ships requires the rock-breaking barge to be drawn aside 30 per cent of the time, the actual work of the barge is 83 blows per hour of work paid to the crew. The average thickness of the rock bed shattered is 2 feet 7½ inches, and it requires about 5.4 blows per cubic yard to shatter the rock. There is considerable range in the cost of the work, but it averages $0.33 per cubic yard, exclusive of general charges. This also does not include the cost of dredging the rock.

Air compressors should be supplied with the coolest and purest air obtainable. For this reason the intake pipe should be extended outside the compressor building. If there be a leak leading from the cylinder to the intake pipe which permits some of the compressed and heated air to return to the intake, there is danger of the compressor becoming very hot and either *exploding the jacket*, or setting fire to any oil that may be present in either cylinder, receiver, or pipe. This burning oil would be forced into the main line of the system and into the mine workings through the exhaust of the drills, an unhealthy if not dangerous thing for the workmen. In some instances of this kind the men have been overcome with carbonic acid gas. *This is known as the inflaming of compressors.—Los Angeles Paper.*

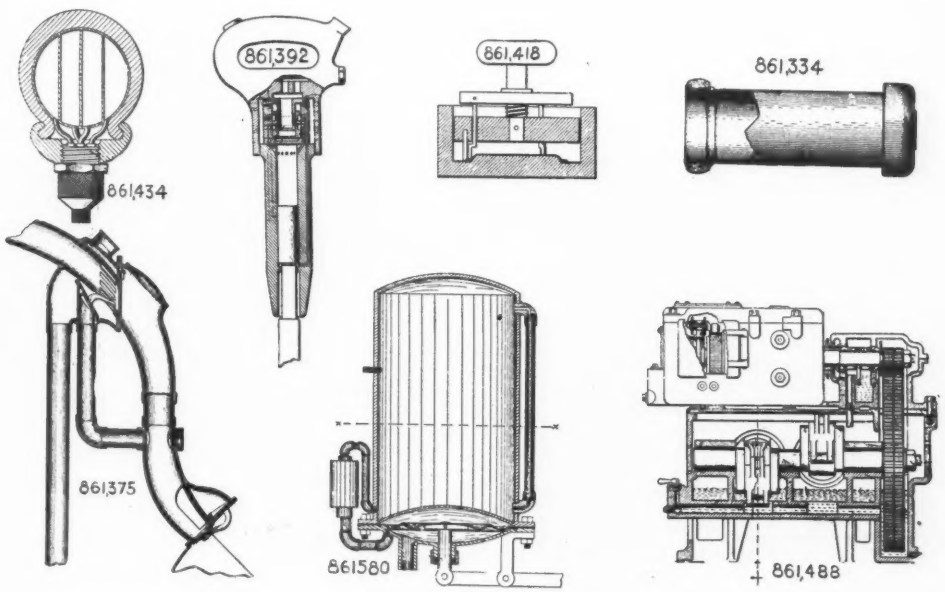
Attempts are to be made to salve from the wreck of H. M. S. "Lutine," which sank off the coast of Holland some one hundred and ten years ago, about £400,000 of bullion, and orders have been given out for the necessary apparatus. The most important part of the equipment will be what might be called an inverted diving bell. It will consist of a long telescopic tube, supported at the top by a barge and terminating at the bottom in a large closed chamber which will be lowered on to the wreck. From this chamber the salving operations will be conducted through air locks. When the mud and sand which have accumulated over and in the wreck have been removed the interior will be cleared by compressed air. It is then hoped that divers will be able to recover the treasure.

The drilling of bolt holes in partially green concrete is a tedious process, owing largely to the frequent wedging of the drill. One contractor seems to have hit upon a simple method of drilling these holes without undergoing the delay incident to wedging. He uses a compressed air drill hung in the guides of a small pile-driver frame, the drill occupying the same position as would the hammer in pile driving. The drill was suspended by a wire rope, and raised or lowered by means of a hand windlass. One advantage of this arrangement was that a longer drill could be used than with the ordinary tripod outfit. A small metal pipe was carried with the drill into the hole, and through this water was forced under a heavy pressure, carrying off the chips, and thus preventing all tendency to wedge. Many such holes have been bored in partially green concrete to a depth of over six feet.—*Engineering Contracting.*

A curious story comes from Germany of the successful opening of a safe by a burglar by means of an oxygen-acetylene blow-pipe. The burglar cut a hole through the ceiling above the safe and lowered a complete blow-pipe apparatus, including an acetylene generator and two cylinders of compressed oxygen through the hole, and by its aid he melted away enough of the door to make the contents of the safe accessible—a tent of heavy blankets having been first built around the safe to prevent the operation being visible.

Protection from such a method of safe cracking by any possible improvement on existing lines of construction would seem to be impossible, and the emergency has called out the suggestion that protection can be obtained by means of apparatus which will liberate deadly fumes whenever the safe is tampered with. Among these is a suggestion for an apparatus which would liberate the fumes of prussic acid, and other suggestions less dangerous to innocent parties.—*American Machinist.*

The sinking of the deepest mineral bore in Great Britain has just been completed at Cameron Bridge. The bore has been put down to the depth of 756 fathoms, or 4,536 feet, and the hurlet or mountain limestone seam, the objective, has been reached. Great difficulties had to be surmounted before the bore reached the lowest point, and these obstacles were responsible for the operation being prolonged for several years. The bore measured 8 inches at the surface and 1¾ inches at the bottom, and the lower coal seams of the East of Fife were satisfactorily proved. The seams of the western district of the county were also pierced, and it is understood they were discovered to be of such thickness as would make working profitable. Mining at a depth of three-quarters of a mile has not yet become an engineering possibility, but within ten years the depth of coal mines has been increased by 100 fathoms, and it is quite probable that the day is not so far distant when the seams passed through could be worked. So far as is known, the next deepest bore in the country was that put down at Gilmerton. Here the depth reached was 500 fathoms. The Scottish Geological Society has taken much interest in the work at Cameron Bridge, and it is stated that an instrument is to be put down to ascertain the temperature at the bottom of the bore.



PNEUMATIC PATENTS, JULY 30

LATEST U. S. PATENTS

Full specifications and drawings of any patent may be obtained by sending five cents (not stamps) to the Commissioner of Patents, Washington, D. C.

JULY 30.

861,270. PNEUMATIC DENTAL CEMENT-INJECTOR. HENRY L. CRUTTENDEN, Northfield, Minn.

861,334. CARRIER FOR PNEUMATIC-DESPATCH TUBES. EDWARD G. THOMAS, New York, N. Y.

861,375. PNEUMATIC-DESPATCH-TUBE APPARATUS. ISAAC W. LITCHFIELD, Boston, Mass.

861,392. PNEUMATIC TOOL. HAROLD R. PRINDLE and JOHN U. ADOLPH, Philadelphia, Pa.

861,418. APPARATUS FOR MAKING PNEUMATIC DIAPHRAGMS. MORRIS S. WRIGHT, Worcester, Mass.

861,434. PNEUMATIC TIRE. THOMAS J. CHATHAM and JAMES S. HOLLIDAY, Turlock, Cal.

861,488. MOTOR-COMPRESSOR. WILLIAM L. WATERS, Milwaukee, Wis., assignor to National Brake and Electric Company, Milwaukee, Wis.

861,580. HYDROPNEUMATIC ENGINE. LEWIS W. EGGLESTON, Appleton, Wis.

862,060. PNEUMATIC OPERATING DEVICE FOR MUSICAL INSTRUMENTS AND MUSICAL-INSTRUMENT PLAYERS. BENJAMIN S. DEAN, San Francisco, Cal.

862,119. PNEUMATIC RENOVATOR. FRANK T. SNYDER, St. Louis, Mo.

AUGUST 6.

862,160. RELIEF MECHANISM FOR COMPRESSORS. EBENEZER HILL and HENRY P. MORGAN, Norwalk, Conn.

862,164. PNEUMATIC PAINT-TOOL. EDWIN F. HULBERT, Kenosha, Wis.

862,333. METHOD OF CREATING A VACUUM. PETER C. HEWITT, New York, N. Y.

862,342. PNEUMATIC-DESPATCH-TUBE APPARATUS. ISAAC W. LITCHFIELD, Boston, Mass.

862,404. ROTARY PUMP, EXHAUSTER, AND BLOWER, &c. FREDERICK LAMPLOUGH, London, England.

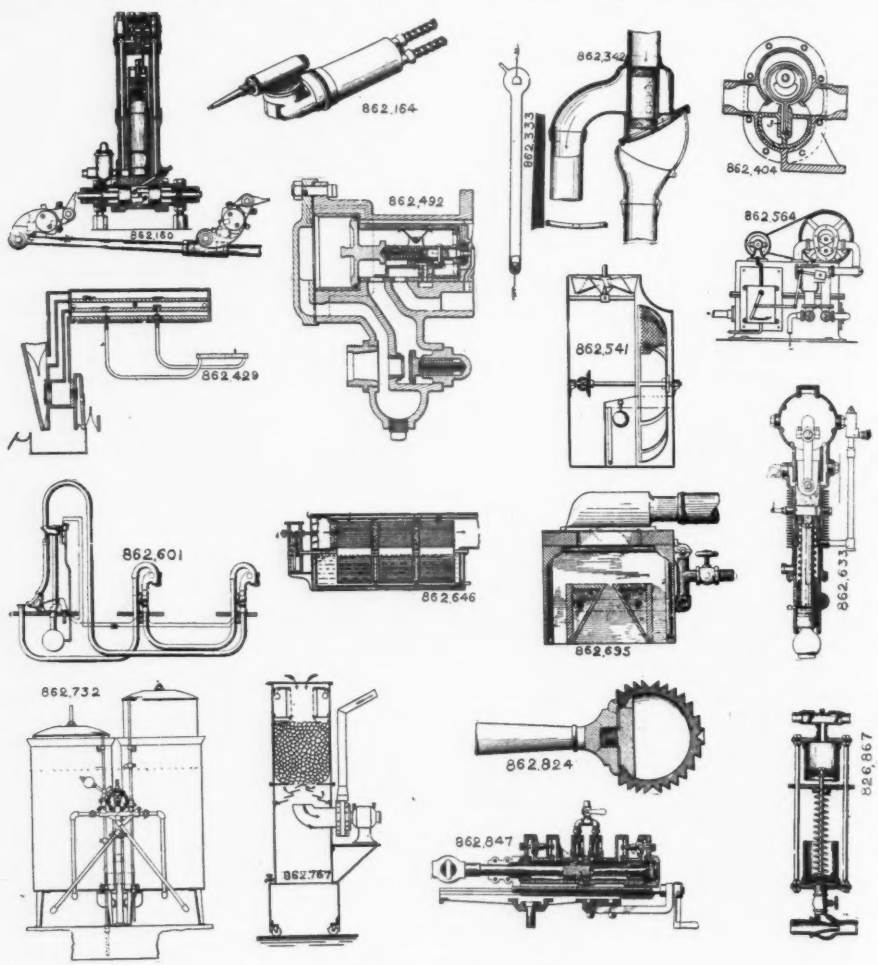
862,429. AUTOPNEUMATIC MUSIC-PLAYING INSTRUMENT. FRANK C. WHITE, Meriden, Conn.

862,492. TRIPLE VALVE FOR AIR-BRAKES. WILLIAM B. MANN, Baltimore, Md.

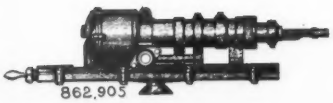
862,541. HUMIDFIER. FRANK B. COMINS, Sharon, Mass.

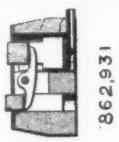
862,564. GAS-COMPRESSOR. ROBERT O. KLATTE, Hamburg, Germany.

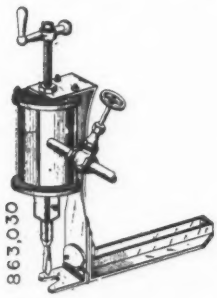
862,601. PNEUMATIC-TUBE SYSTEM. BIRNEY C. BATCHELLER, Philadelphia, Pa.

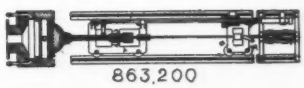


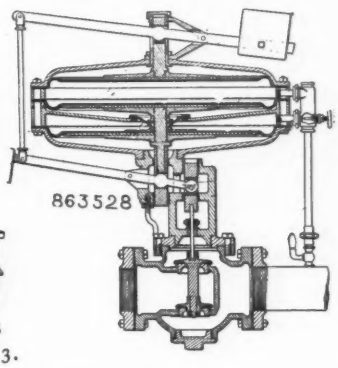
PNEUMATIC PATENTS, AUGUST 6.

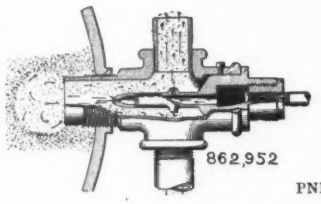


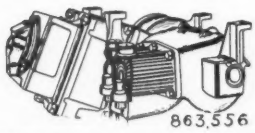












PNEUMATIC PATENTS, AUGUST 13.

862,646. AIR AND WATER COOLING APPARATUS. JOHN LITTLE, Camberwell, near Melbourne, Victoria, Australia.

862,653. ROCK-DRILL. HOWARD A. PEDRICK and CHARLES A. SMITH, Philadelphia, Pa.

862,695. PNEUMATIC CARPET-CLEANING DEVICE. CHARLES S. BALDWIN, San Francisco, Cal.

862,696. GOVERNING MECHANISM FOR PNEUMATIC-TUBE SYSTEMS. BIRNEY C. BATCHELLER, Philadelphia, Pa.

862,767. AIR-COOLING APPARATUS. OTTO STERKEL, Ravensburg, Germany.

862,732. APPARATUS FOR SUPPLYING AIR AND REGULATING PRESSURE THEREOF. EDWIN A. HALL, Hyde Park, Mass.

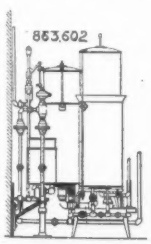
862,824. PNEUMATIC CLEANING DEVICE. LEWIS O. HOWELL, Philadelphia, Pa.

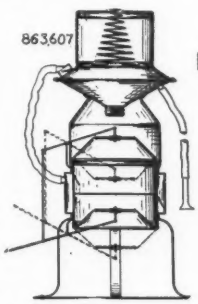
862,847. GAS-ACTUATED ROCK-DRILL. JOHN V. RICE, JR., Edgewater Park, N. J.

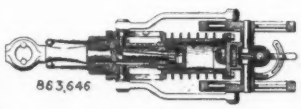
862,867. PNEUMATIC PUMPING APPARATUS. LEWIS W. EGGLESTON, Appleton, Wis.

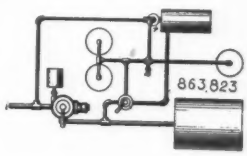
AUGUST 13.

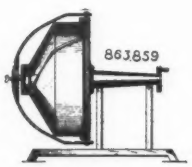
862,905. PNEUMATIC DRILL. FREDERICK HART, Poughkeepsie, N. Y.

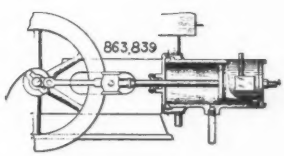


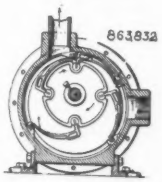


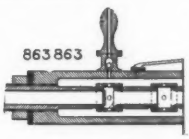


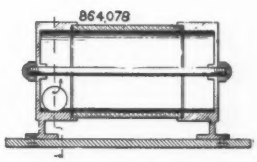


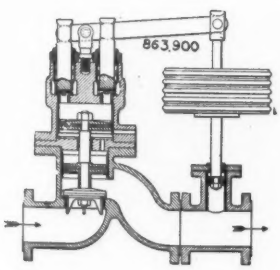


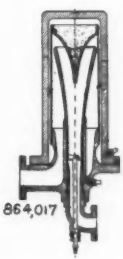


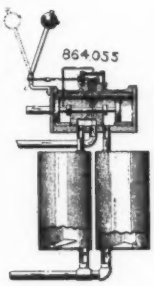


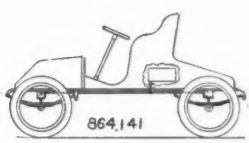












PNEUMATIC PATENTS, AUGUST 20.

862,931. PNEUMATIC DEVICE FOR OPERATING GAS-VALVES. Richard N. Oakman, Brooklyn, N. Y.

862,952. PNEUMATIC TRACK-SANDER. John H. Watters, Augusta, Ga.

863,030. PORTABLE AIR-DRILL. Swan P. Johnson, Clinton, Iowa.

863,200. AIR-REGULATING DEVICE FOR GLASS-DRAWING MACHINES. Ira A. Milliron, Franklin, Pa.

863,528. FLUID-PRESSURE REGULATOR. Louis B. Fulton, Pittsburg, Pa.

863,556. MOTOR-DRIVEN AIR-COMPRESSOR Edward D. Priest and Einar J. Bring, Schenectady, N. Y.

August 20.

863,602. AIR-SUPPLYING AND PRESSURE-REGULATING MEANS FOR AIR AND GAS MIXING APPARATUS. Edwin A. Hall, Hyde Park, Mass.

863,607. DUST-ASPIRATING APPARATUS. Christian F. Holder, Metzingen, Germany.

863,646. HYDROCARBON ROCK-DRILL. John V. Rice, Jr., Edgewater Park, N. J.

863,823. COMBINED AUTOMATIC AND STRAIGHT AIR BRAKE. Edward A. Wright, Edgewood Park, Pa.

863,832. POSITIVE-PRESSURE BLOWER. Francis P. Boland, Providence, R. I.

863,839. POWER APPARATUS. William W. Flickinger, Bradford, Pa.

Claim.—In a combination in an air-compressing engine, a cylinder, a piston, means for admitting motive fluid to one end of the cylinder air inlet and discharge means for the other end whereby the air is drawn in on one stroke and discharged on the reverse stroke, means for destroying the partial vacuum as the piston reaches the end of its suction stroke, said means consisting of a port so located as to be uncovered as the piston completes its stroke in either direction, thereby acting on one stroke as an exhaust port and on the opposite stroke as an air inlet port, substantially as described.

863,859. PNEUMATIC BUTTER-SEPARATOR. La Fayette Lillard, Bootjack, Cal.

863,863. APPARATUS FOR CREATING AND MAINTAINING A VACUUM. Albert Manvers and Henry Phillips, Sydney, New South Wales, Australia.

863,900. APPARATUS FOR REGULATING PRESSURE IN PIPES. John B. Broadhead, Wellholme, Brighouse, England.

864,017. PRODUCTION OF FLUID FOR POWER. Francesco Miller, Turin, Italy.

864,055. COMPRESSED-AIR WATER-ELEVATOR. Frank Allison, Chattanooga, Tenn.

864,078. AIR-PURIFYING APPARATUS. George Clements and James M. Hostler, Chicago, Ill.

864,141. COMPRESSED-AIR-CUSHION MECHANISM FOR AUTOMOBILES. Thomas F. Scott, Everett, Mass.

August 27.

864,220. PNEUMATIC ENGINE. Edwin D. Ackerman, New York, and Charles E. Clinton and Robert N. Eltom, Corona, N. Y.

864,270. DRILL-CHUCK FOR USE ON HAMMER ROCK-DRILLS. Albert L. Stephens and Thomas McGrath, Silver Plume, Colo.

864,284. PNEUMATIC OIL-CAN. John S. Arnott and Eugene L. Arnott, Greenfield, Ohio.

864,339. AIR-PUMP AND AUTOMATIC PRESSURE-REGULATOR THEREFOR. Gottfried Schmidt, Hazleton, Pa.

864,344. FLUID-PRESSURE SYSTEM. Samuel B. Stewart, Jr., Schenectary, N. Y.

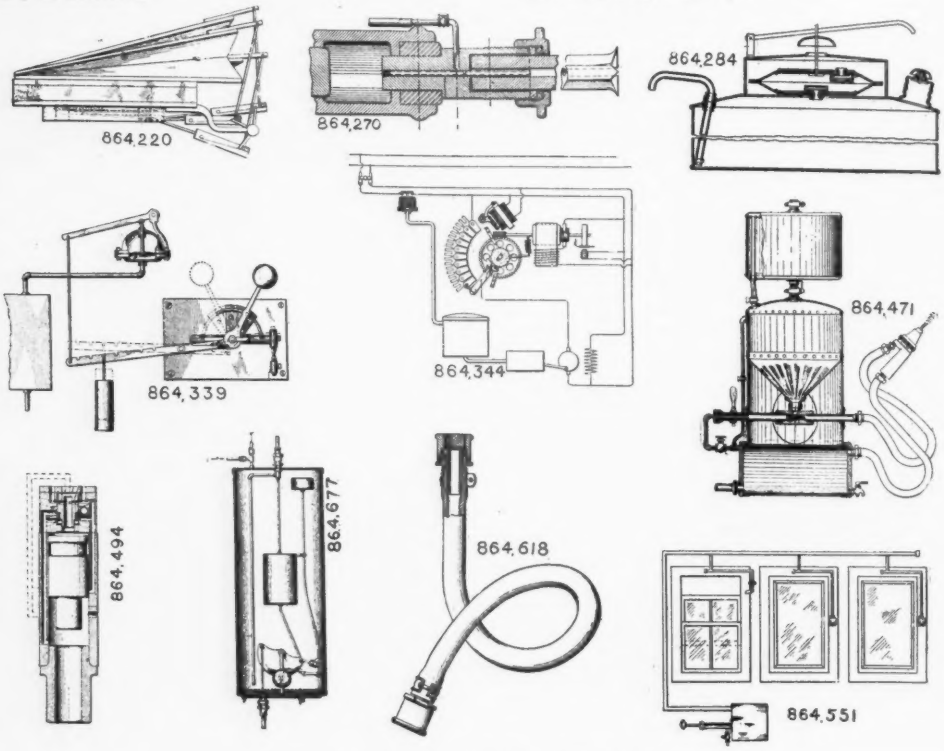
864,471. SAND-BLAST APPARATUS. William H. Kelly, San Francisco, Cal.

864,494. PNEUMATIC TOOL. Wilber H. Van Sickel, Philadelphia, Pa.

864,551. PNEUMATIC SYSTEM FOR CONTROL OF WINDOWS. Joseph B. McKeown, Union Hill, N. J.

864,618. PIPE-COUPLING. Louis V. Deloche, Monongahela, Pa.

864,677. HYDRAULIC AIR-COMPRESSOR. Jett E. Nash, Cheyenne, Wyo.



PNEUMATIC PATENTS, AUGUST 27.

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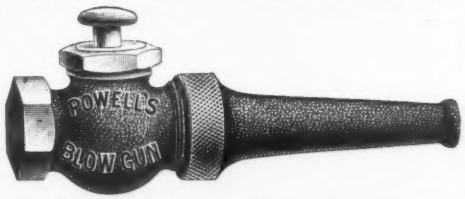

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Cocks.
Powell Co., Wm.
Compressors, Air and Gas.
Blaisdell Machinery Co.
Bury Compressor Co.
Chicago Pneumatic Tool Co.
Curtis & Co. Mfg. Co.
General Compressed Air and Vacuum Machinery Co.
Harris Air Pump Co.
Ingersoll-Rand Co.
McKiernan Drill Co.
Powell Co., Wm.
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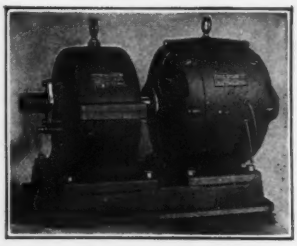

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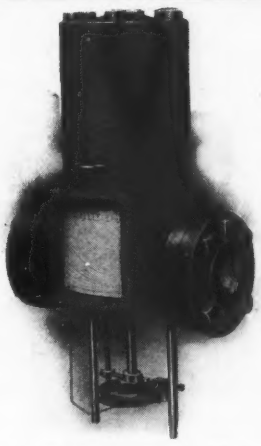

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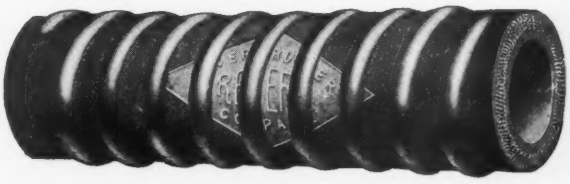

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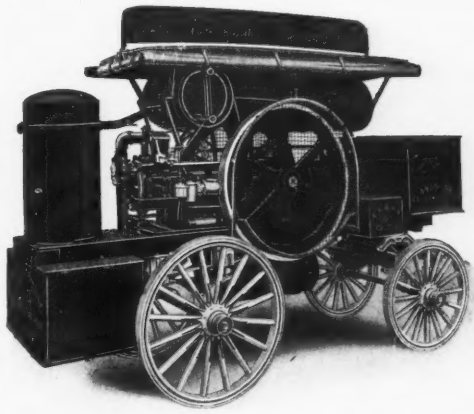

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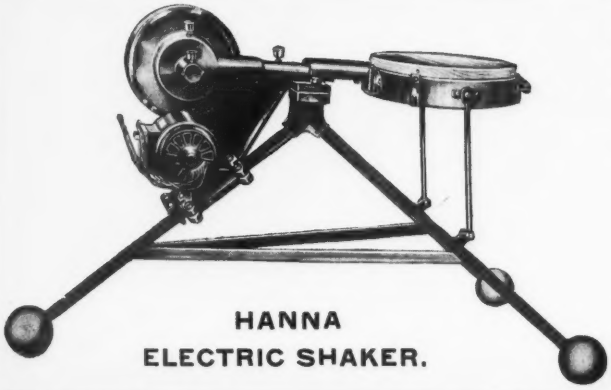

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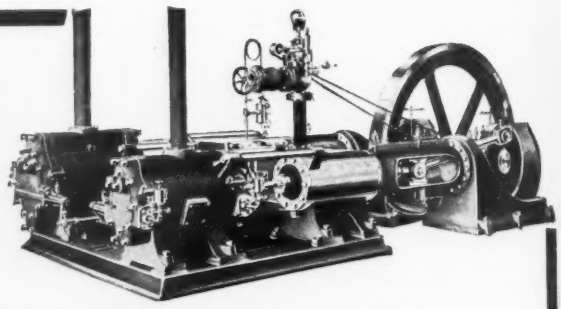

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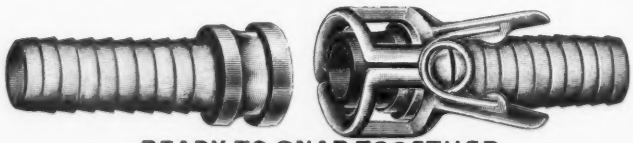

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